NFPA® 652

Standard on the Fundamentals of Combustible Dust

2019

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NFPA® 652

Standard on

the Fundamentals of Combustible Dust

2019 Edition

This edition of NFPA 652, *Standard on the Fundamentals of Combustible Dust,* was prepared by the Technical Committee on Fundamentals of Combustible Dusts and released by the Correlating Committee on Combustible Dusts. It was issued by the Standards Council on May 4, 2018, with an effective date of May 24, 2018, and supersedes all previous editions.

This edition of NFPA 652 was approved as an American National Standard on May 24, 2018.

Origin and Development of NFPA 652

NFPA 652, *Standard on the Fundamentals of Combustible Dust*, provides the general requirements for management of combustible dust fire and explosion hazards and directs the user to NFPA's industry- or commodity-specific standards, as appropriate: NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*; NFPA 484, *Standard for Combustible Metals*; NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*; NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*; and NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*. This new standard establishes the relationship and hierarchy between it and any of the industry- or commodity-specific standards, ensuring that fundamental requirements are addressed consistently across industries, processes, and dust types.

While NFPA has addressed combustible dust hazards and safeguards for flour and pulverized fuels, such as coal, as far back as 1920, it was not until 2003 that users from all sectors comprehensively examined the specific requirements contained in the five commodity-specific NFPA standards. Those documents apply broadly to varied facilities, processes, equipment types, and dust types to protect against the hazards from combustible dust fires and explosions.

A basis for safety embedded in each of those standards requires the fuel — in this case dust — to be managed, ignition sources to be controlled, and impact from an explosion to be limited through construction, protection, isolation, and housekeeping.

Some users of the NFPA commodity-specific standards believed that the requirements were inconsistent between the various industry sectors and the dust types, leading to confusion in determining which standard applied and how to protect similar hazards within a given process.

In response to that perceived challenge to the longstanding NFPA combustible dust standards, NFPA staff addressed the question of whether there was a better way to structure the committees and standards. Working through the direction of the NFPA Standards Council, a task group chaired by a member of the council explored options for restructuring the combustible dust project. The task group consisted of the chairs of the technical committees for the four existing commodity-specific standards, an additional member from each committee, and NFPA staff liaisons. A report presented to the Standards Council at its March 2011 meeting contained two key recommendations: the establishment of a correlating committee to oversee the work of the four existing combustible dust committees, as well as the work of a proposed new Technical Committee on Fundamentals of Combustible Dusts, and the establishment of a new committee whose scope would permit it to develop documents on the management of hazards from combustible dusts and combustible particulate solids.

The Technical Committee on Fundamentals of Combustible Dusts began its work in earnest in early 2012, using task groups to develop draft chapters based on a straw-man outline proposed by the committee. A preliminary draft was developed and approved by the committee to serve as the basis for requesting approval from the NFPA Standards Council to establish a specific revision cycle. The council initially approved the development of NFPA 652 for the Fall 2014 cycle; during the second draft stage of the process, however, the committee requested more time to review and process the extensive public comments received. That request was approved, and the standard was moved to the Annual 2015 cycle.

Hazard awareness appears prominently in the standard through the inclusion of chapters on hazard identification, hazard analysis or evaluation, and hazard management involving hazard prevention or mitigation. The committee made some of the requirements in NFPA 652 apply retroactively, including dust hazards analysis (DHA). For existing facilities, a DHA is permitted to be phased in and completed no later than 3 years from the effective date of the standard. Because so many of the investigation findings conclude that owners/operators appear to be unaware of the hazards posed by combustible particulate solids that have the potential to form combustible dusts when processed, stored, or handled, the committee believed it essential to establish the DHA as a fundamental step in creating a plan for safeguarding such facilities.

Together with NFPA 652, the combustible dust standards speak directly to such critical factors as dust containment and collection, hazard analysis, testing, ventilation, air flow, housekeeping, and fire suppression. The provisions of this standard incorporate many of the lessons learned and recommendations issued as part of the combustible dust incident investigation findings reported by the Chemical Safety Board. In addition, this standard complements the efforts of the Occupational Safety and Health Administration and its National Emphasis Program on combustible dust.

The first edition of NFPA 652 was dedicated to the memory of workers who suffered and lost their lives from the hazards of combustible dusts in the hope that it helps prevent such tragedies in the future.

The 2019 edition of NFPA 652 contains the following changes:

(1) NFPA 652 is intended to be the fundamentals document for combustible dust. As such, definitions that are considered fundamental to the topic of combustible dust reside in NFPA 652 and be extracted into the industry and commodity-specific standards. This ensures consistency in documents dealing with dust. Changes to this edition reflect this, and several definitions are added from industry and commodity-specific documents that also are considered fundamental to combustible dust.
(2) Provisions designate the requirements that are meant to be retroactive. Management system requirements, such as housekeeping, personal protective equipment (PPE), and hot work are now in Chapter 8, Management Systems.
(3) Material is added to Chapter 5 that helps the user evaluate the requirements for mixtures of types of combustible dust, such as a mixture containing metal dust and agricultural dust.
(4) Changes to the deadlines are included for the completion of dust hazard analysis (DHA) for existing processes and facility compartments. The deadline for completion of a DHA is now September 7, 2020. This aligns with industry and commodity-specific dust standards. NFPA 652 now also requires that the DHA be reviewed and updated every 5 years.
(5) Chapter 9, Hazard Management: Mitigation and Prevention, is expanded to include requirements on equipment design and operation. This includes air material separators (AMS), air moving devices (AMDs), duct systems, sight glasses, abort gates and dampers, bulk storage enclosures, size reduction equipment, pressure protection systems, material feeding devices, bucket elevators, enclosed conveyors, mixers and blenders, and dryers. Requirements for fans for continuous dust control are also added. Changes are made to the requirements for equipment isolation to remove the exemption for small diameter ductwork. Note that this is consistent with the current requirements in NFPA 654.
(6) The committee modified the material on electrostatic discharges to provide clarity to the user regarding conductive equipment, bonding and grounding, flexible connectors, particulate transport rates, grounding of personnel, flexible intermediate bulk containers (FIBCs), and rigid intermediate bulk containers (RIBCs).

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Committee Scope: This Committee shall have primary responsibility for documents on the hazard identification, prevention, control, and extinguishment of fires and explosions in the design, construction, installation, operation, and maintenance of facilities and systems used in manufacturing, processing, recycling, handling, conveying, or storing combustible particulate solids, combustible metals, or hybrid mixtures.

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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.

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Information on referenced publications can be found in Chapter 2 and Annex D.

Chapter 1 Administration

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

1.2 Purpose. This standard shall provide the minimum general requirements necessary to manage the fire, flash fire, and explosion hazards posed by combustible dusts and directs the user to other NFPA standards for industry- and commodity-specific requirements.

1.3 Application.

1.3.1 The user shall be permitted to use Figure 1.3.1 for guidance when using this standard. See Figure 1.3.1.

1.3.2 This standard shall apply to all facilities and operations that manufacture, process, blend, convey, repackage, generate, or handle combustible dusts or combustible particulate solids.

1.3.3 This standard shall not apply to the following:

(1) Storage or use of consumer quantities of such materials on the premises of residential or office occupancies
(2) Storage or use of commercially packaged materials at retail facilities
(3) Such materials displayed in original packaging in mercantile occupancies and intended for personal or household use or as building materials
(4)* Warehousing of sealed containers of such materials when not associated with an operation that handles or generates combustible dust
(5) Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes

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

(1) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*
(2) NFPA 484, *Standard for Combustible Metals*
(3) NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*
(4) NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*
(5) NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*

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

1.4.3 Where an industry- or commodity-specific NFPA standard specifically prohibits a requirement specified in this standard, the prohibition in the industry- or commodity-specific NFPA standard shall be applied.

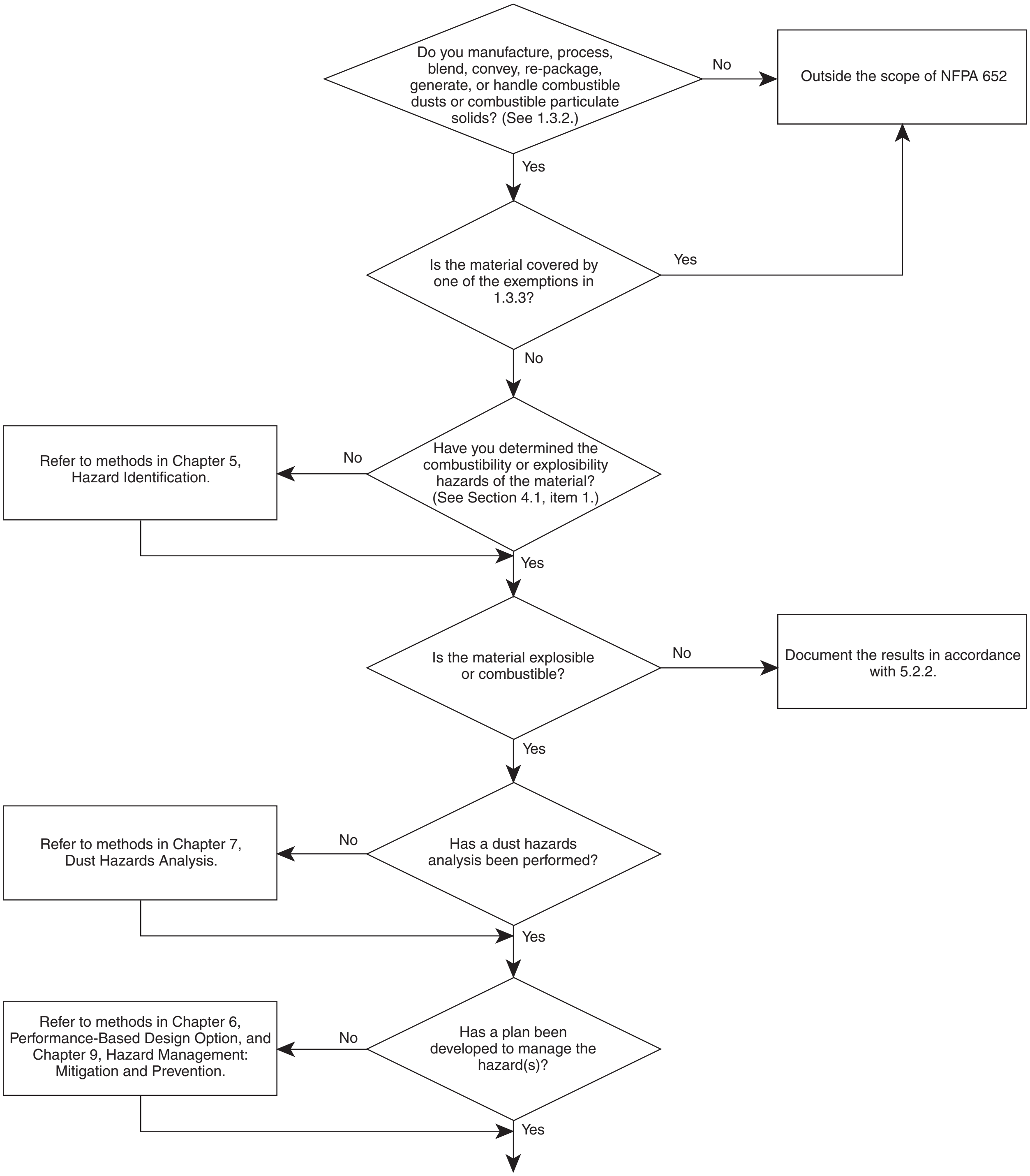
1.4.4 Where an industry- or commodity-specific NFPA standard neither prohibits nor provides a requirement, the requirement in this standard shall be applied.

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

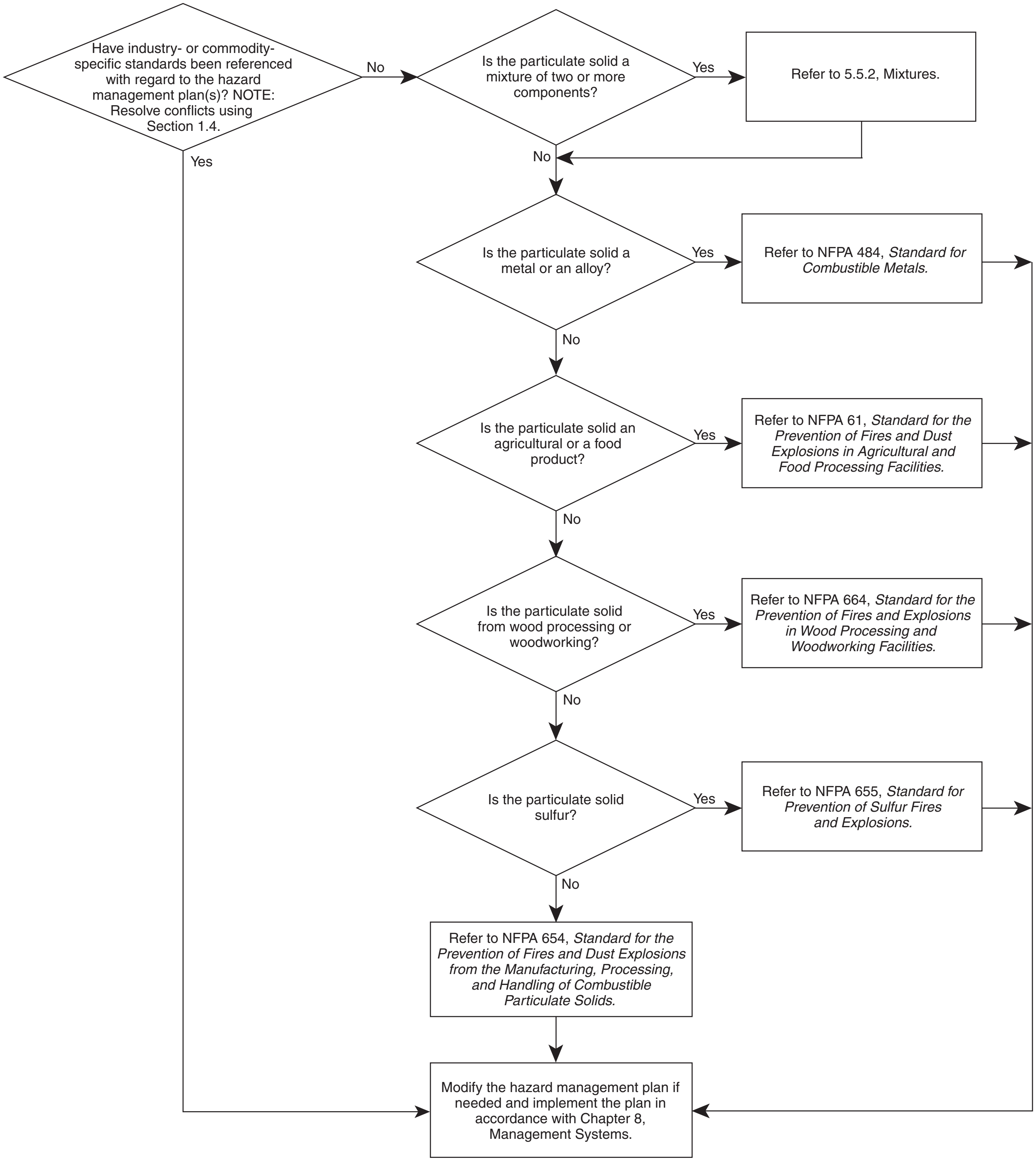
1.5 Retroactivity.

1.5.1 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.

1.5.2 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.



Δ **FIGURE 1.3.1 Document Flow Diagram for Combustible Dust Hazard Evaluation.**



Δ **FIGURE 1.3.1** ***Continued***

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

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

1.6 Equivalency.

1.6.1 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.

1.6.2 Technical documentation shall be made available to the authority having jurisdiction to demonstrate equivalency.

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

1.7 Units and Formulas.

1.7.1 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).

1.7.2* 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.

1.7.3 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 10, *Standard for Portable Fire Extinguishers,* 2018 edition.

NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2016 edition.

NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2018 edition.

NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2018 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2019 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2016 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2017 edition.

NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2015 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2017 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2019 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection,* 2018 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2019 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2017 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2016 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2019 edition.

NFPA 54, *National Fuel Gas Code,* 2018 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities,* 2017 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2014 edition.

NFPA 70®, National Electrical Code®, 2017 edition.

NFPA 72®, National Fire Alarm and Signaling Code®, 2019 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2015 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2019 edition.

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

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2018 edition.

NFPA 484, *Standard for Combustible Metals,* 2019 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2018 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2017 edition.

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions,* 2017 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities,* 2017 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems,* 2019 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2018 edition.

NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire,* 2018 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire,* 2015 edition.

2.3 Other Publications.

N **2.3.1 AMCA Publication.** Air Movement and Control Association International, Inc., 30 West University Drive, Arlington Heights, IL 60004-1893.

AMCA 99-0401-86, *Classification for Spark Resistant Construction,* 1986.

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

ASME B31.3, *Process Piping*, 2016.

Boiler and Pressure Vessel Code, 2017.

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

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, 2012a.

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2014.

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

IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, 2014.

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N **2.3.5 ISA Publications.** International Society of Automation, 67 T. W. Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709.

ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector*, 2004.

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

UN Recommendations on the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria, 2011.

2.3.7 U.S. Government Publications. U.S. Government Publishing Office, 732 North Capitol Street, NW, Washington, DC 20401-0001.

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

2.3.8 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2014 edition.
NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.
NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.
NFPA 77, *Recommended Practice on Electricity*, 2019 edition.
NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2018 edition.
NFPA 484, *Standard for Combustible Metals*, 2019 edition.
NFPA 921, *Guide for Fire and Explosion Investigations*, 2017 edition.
NFPA 1250, *Recommended Practice in Fire and Emergency Service Organization Risk Management*, 2015 edition.
NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program*, 2018 edition.
NFPA 5000®, Building Construction and Safety Code®, 2018 edition.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

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

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

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. An NFPA Standard, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and that is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions are not to be considered a part of the requirements of a standard and shall be located in an appendix, annex, footnote, informational note, or other means as permitted in the NFPA Manuals of Style. When used in a generic sense, such as in the phrase "standards development process" or "standards development activities," the term "standards" includes all NFPA Standards, including Codes, Standards, Recommended Practices, and Guides.

3.3 General Definitions.

N **3.3.1 Abort Gate/Damper.** A device for the quick diversion of material or air to the exterior of a building or other safe location in the event of a fire.

Δ **3.3.2* Air-Material Separator (AMS).** A device designed to separate the conveying air from the material being conveyed.

3.3.2.1 ***Enclosureless AMS.*** An air-material separator designed to separate the conveying air from the material being conveyed where the filter media are not enclosed or in a container.

Δ **3.3.3* Air-Moving Device (AMD).** A power-driven fan, blower, or other device that establishes an airflow by moving a given volume of air per unit time.

3.3.4 Bonding. For the purpose of controlling static electric hazards, the process of connecting two or more conductive objects by means of a conductor so that they are at the same electrical potential but not necessarily at the same potential as the earth.

Δ **3.3.5* Centralized Vacuum Cleaning System.** A fixed-pipe system utilizing variable-volume negative-pressure (i.e., vacuum) air flows from remotely located hose connection stations to allow the removal of dust accumulations from surfaces and conveying those dusts to an air-material separator (AMS).

Δ **3.3.6* Combustible Dust.** A finely divided combustible particulate solid that presents a flash-fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations.

Δ **3.3.7* Combustible Metal.** Any metal composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that will burn.

3.3.8* Combustible Particulate Solid. Any solid material composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that, when processed, stored, or handled in the facility, has the potential to produce a combustible dust.

3.3.9 Compartment. A subdivision of an enclosure.

N **3.3.10* Conductive.** Possessing the ability to allow the flow of an electric charge.

3.3.10.1 ***Conductive Dusts.*** Dusts with a volume resistivity of less than 10^6 ohm-m.

3.3.11* Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [**68,** 2018]

3.3.12 Detachment. Location in a separate building or an outside area removed from other structures to be protected by a distance as required by this standard.

N **3.3.13* Dissipative.** A material or a construction that will reduce static charge to acceptable levels. [**77**, 2019]

3.3.14 Duct. Pipes, tubes, or other enclosures used to convey materials pneumatically or by gravity.

3.3.15* Dust Collection System. A combination of equipment designed to capture, contain, and pneumatically convey fugitive dust to an air-material separator (AMS) in order to remove the dust from the process equipment or surrounding area.

3.3.16 Dust Deflagration Hazard. A condition that presents the potential for harm or damage to people, property, or the environment due to the combustion of a sufficient quantity of combustible dust suspended in air or another oxidizing medium.

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

3.3.18* Dust Hazards Analysis (DHA). A systematic review to identify and evaluate the potential fire, flash fire, or explosion hazards associated with the presence of one or more combustible particulate solids in a process or facility.

3.3.19* Enclosure. A confined or partially confined volume. [**68,** 2018]

N **3.3.20* Explosible.** Capable of propagating a deflagration when dispersed in air or the process-specific oxidizing media.

3.3.21 Explosion. The bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration. [**69,** 2014]

Δ **3.3.22 Fire Hazard.** Any situation, process, material, or condition that can cause a fire or provide a ready fuel supply to augment the spread or intensity of a fire and poses a threat to life or property.

3.3.23* 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,** 2017]

3.3.24 Fuel Object. A combustible object or mass of particulate that can serve as a source of fuel for a fire or deflagration; sometimes referred to as a *fuel package.*

3.3.25 Fugitive Dusts. Dust that escapes from equipment and containers.

3.3.26 Grounding. The process of bonding one or more conductive objects to the ground so that all objects are at zero electrical potential; also referred to as *earthing.*

3.3.27 Hot Work. Work involving burning, welding, or a similar operation that is capable of initiating fires or explosions. [**51B,** 2019]

3.3.28* Hybrid Mixture. An explosible heterogeneous mixture, comprising gas with suspended solid or liquid particulates, in which the total flammable gas concentration is ≥10 percent of the lower flammable limit (LFL) and the total suspended particulate concentration is ≥10 percent of the minimum explosible concentration (MEC). [**68,** 2018]

3.3.29* Industry- or Commodity-Specific NFPA Standard. An NFPA code or standard whose intent as documented within its purpose or scope is to address fire and explosion hazards of a combustible particulate solid.

3.3.30 Intermediate Bulk Containers.

Δ **3.3.30.1*** ***Flexible Intermediate Bulk Container (FIBC).*** Large bags typically made from nonconductive woven fabric that are used for storage and handling of bulk solids.

Δ **3.3.30.1.1** ***Type A FIBC.*** An FIBC made from nonconductive fabric with no special design features for control of electrostatic discharge hazards.

Δ **3.3.30.1.2** ***Type B FIBC.*** An FIBC made from nonconductive fabric where the fabric or the combination of the fabric shell, coating, and any loose liner has a breakdown voltage of less than 6000 volts.

Δ **3.3.30.1.3** ***Type C FIBC.*** An FIBC made from conductive material or nonconductive woven fabric incorporating interconnected conductive threads of specified spacing with all conductive components connected to a grounding tab.

Δ **3.3.30.1.4** ***Type D FIBC.*** An FIBC made from fabric and/or threads with special static properties designed to control electrostatic discharge energy without a requirement for grounding the FIBC.

Δ **3.3.30.2*** ***Rigid Intermediate Bulk Container (RIBC).*** An intermediate bulk container (IBC) that can be enclosed in or encased by an outer structure consisting of a steel cage, a single-wall metal or plastic enclosure, or a double wall of foamed or solid plastic.

Δ **3.3.30.2.1** ***Insulating RIBC.*** An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded.

N **3.3.31** ***K_{St}.*** The deflagration index of a dust cloud. [**68,** 2018]

Δ **3.3.32* 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.

Δ **3.3.33* Minimum Ignition Energy (MIE).** The lowest capacitive spark energy capable of igniting the most ignition-sensitive concentration of a flammable vapor–air mixture or a combustible dust–air mixture as determined by a standard test procedure.

N **3.3.34* Mixture.** A combination of particulates incorporating more than one material.

N **3.3.35* Nonconductive.** A material or a construction that has the ability to accumulate charge, even when in contact with ground.

3.3.36* Pneumatic Conveying System. An equipment system that transfers a controlled flow of solid particulate material from one location to another using air or other gases as the conveying medium, and that is comprised of the following components: a material feeding device; an enclosed ductwork, piping, or tubing network; an air–material separator; and an air-moving device.

N **3.3.37 Portable Vacuum Cleaner.** A movable assembly consisting basically of a vacuum source [air-moving device (AMD)], an air-material separator (AMS) using either liquid or filter media within an enclosure, and a vacuum hose, used to remove dusts and particles from surfaces.

Δ **3.3.38 Pyrophoric Material.** A material that ignites upon exposure to air at or below 54.4°C (130°F). [**484,** 2019]

3.3.39 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,** 2018]

3.3.40 Replacement-in-Kind. A replacement that satisfies the design specifications of the replaced item.

3.3.41* Risk Assessment. An assessment of the likelihood, vulnerability, and magnitude of the incidents that could result from exposure to hazards. [**1250,** 2015]

3.3.42 Segregation. A hazard management strategy in which a physical barrier is established between the hazard area and an area to be protected.

3.3.43 Separation. A hazard management strategy achieved by the establishment of a distance as required by the standard between the combustible particulate solid process and other operations that are in the same room.

3.3.44* Spark. A localized source of thermal or electrical energy capable of igniting combustible material.

N **3.3.44.1*** ***Capacitive Spark.*** A short-duration electric discharge due to a sudden breakdown of air or some other insulating material separating two conductors at different electric potentials, accompanied by a momentary flash of light; also known as electric spark, spark discharge, and sparkover.

N **3.3.44.2*** ***Thermal Spark.*** A moving particle of solid material that emits radiant energy sufficient to act as an ignition source due to either its temperature or the process of combustion on its surface.

3.3.45 Threshold Housekeeping Dust Accumulations. The maximum quantity of dust permitted to be present before cleanup is required.

3.3.46 Transient Releases. (Reserved)

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

3.3.48 Wall.

3.3.48.1 ***Fire Barrier Wall.*** A wall, other than a fire wall, having a fire resistance rating. [**221,** 2018]

3.3.48.2 ***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,** 2018]

N **3.3.49 Wet Air-Material Separator.** An air-material separator (AMS) that uses liquid for the separation of the pneumatically conveyed solid from the air/gas.

Chapter 4 General Requirements

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

(1) Determining the combustibility and explosibility hazards of materials in accordance with Chapter 5
(2) Identifying and assessing any fire, flash fire, and explosion hazards in accordance with Chapter 7
(3) Managing the identified fire, flash fire, and explosion hazards in accordance with 4.2.3
(4) Communicating the hazards to affected personnel in accordance with Section 8.8

4.2 Objectives. The objectives stated in this section shall be interpreted as intended outcomes of this standard and not as prescriptive requirements.

4.2.1 Life Safety.

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

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

4.2.1.3 The facility, processes, and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably prevent injury from explosions.

4.2.1.4 The structure shall be located, designed, constructed, and maintained to reasonably protect adjacent properties and the public from the effects of fire, flash fire, or explosion.

4.2.2* Mission Continuity. The facility, processes, and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to limit damage to levels that ensure the ongoing mission, production, or operating capability of the facility to a degree acceptable to the owner/operator.

4.2.3* Mitigation of Fire Spread and Explosions. The facility and processes shall be designed to prevent or mitigate fires and explosions that can cause failure of adjacent buildings or building compartments or other enclosures, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements.

Δ **4.2.4* Compliance Options.** The objectives in Section 4.2 shall be deemed to have been met by implementing either of the following:

(1) A prescriptive approach in accordance with Chapters 5, 7, 9, and 8 in conjunction with any prescriptive provisions of applicable commodity-specific NFPA standards
(2) A performance-based approach in accordance with Chapter 6

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

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

Chapter 5 Hazard Identification

5.1 Responsibility. The owner/operator of a facility with potentially combustible dusts shall be responsible for determining whether the materials are combustible or explosible, and, if so, for characterizing their properties as required to support the DHA.

5.1.1 Where dusts are determined to be combustible or explosible, the hazards associated with the dusts shall be assessed in accordance with Chapter 7.

5.1.2 Where dusts are determined to be combustible or explosible, controls to address the hazards associated with the dusts shall be identified and implemented in accordance with 4.2.4.

5.2* Screening for Combustibility or Explosibility.

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

(1) Historical facility data or published data that are deemed to be representative of current materials and process conditions
(2) Analysis of representative samples in accordance with the requirements of 5.4.1 and 5.4.3

5.2.2* Test results, historical data, and published data shall be documented and, when requested, provided to the authority having jurisdiction (AHJ).

5.2.3 The absence of previous incidents shall not be used as the basis for deeming a particulate to not be combustible or explosible.

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

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

5.4 Combustibility and Explosibility Tests. Where combustibility or explosibility screening tests are required, they shall be conducted on representative samples obtained in accordance with Section 5.5.

5.4.1 Determination of Combustibility.

5.4.1.1 Where the combustibility is not known, determination of combustibility shall be determined by one of the following tests:

(1) 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, "Test Method for Readily Combustible Solids"
(2) Other equivalent fire exposure test methods

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

5.4.1.3 If the dust is known to be explosible, it shall be permitted to assume that the dust is combustible and the requirements of 5.4.1.1 shall not apply.

5.4.2* Determination of Flash-Fire Potential. (Reserved)

5.4.3 Determination of Explosibility.

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

(1) The "Go/No-Go" screening test methodology described in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*
(2) ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*
(3) An equivalent test methodology

5.4.3.2* When determining explosibility, it shall be permitted to test a sample sieved to less than 200 mesh (75 μm).

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

5.4.3.4 It shall be permitted to assume a material is explosible, forgoing the requirements of 5.4.3.1.

5.4.3.5* When the representative sample has a characteristic particle size smaller than 0.5 μm, the explosibility screening test method shall account for possible ignitions in the sample injection apparatus.

5.4.4 Quantification of Combustibility and Explosibility Characteristics.

5.4.4.1* Where dusts are determined to be combustible or explosible, additional testing shall be performed, as required, to acquire the data necessary to support the performance-based design method described in Chapter 6; the DHA described in Chapter 7; the risk assessments described in Chapter 9; or specification of the hazard mitigation and prevention described in Chapter 9.

5.4.4.2 The owner/operator shall be permitted to use the worst-case characteristics of the various materials being handled as a basis for design.

N **5.4.4.3** When quantifying combustibility and explosibility characteristics, it shall be permitted to test the as-received sample only for those locations where the particulate remains homogeneously mixed.

N **5.4.4.4*** Where the material does not remain homogeneously mixed, a representative fine fraction shall be tested.

5.5 Sampling.

5.5.1 Sampling Plan.

5.5.1.1 A sampling plan shall be developed and documented to provide data as needed to comply with the requirements of this chapter.

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

5.5.1.3 The sampling plan shall include the following:

(1) Identification of locations where fine particulates and dust are present
(2) Identification of representative samples
(3) Collection of representative samples
(4)* Preservation of sample integrity
(5) Communication with the test laboratory regarding sample handling
(6) Documentation of samples taken
(7) Safe sample collection practices

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

N **5.5.2.1** Mixtures comprised of more than 10 percent by mass of metallic particulate shall be treated as a metallic combustible dust in accordance with the relevant sections of NFPA 484.

N **5.5.2.1.1** It shall be permitted to evaluate metal mixtures per the requirements in 1.1.6.2 of NFPA 484.

N **5.5.2.1.1.1** Mixtures containing metals identified as legacy metals (aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium) shall be evaluated per the requirements in 1.1.6.2 of NFPA 484.

N **5.5.2.2** Mixtures consisting of more than 50 percent by mass wood or wood-based particulate but less than 10 percent metallic particulate shall be treated as a wood dust in accordance with the relevant sections of NFPA 664.

N **5.5.2.3** Mixtures consisting of more than 50 percent by mass agricultural particulate to be used in foodstuffs but less than 10 percent metallic particulate shall be treated as an agricultural dust in accordance with the relevant sections of NFPA 61.

N **5.5.2.4** Any mixture that does not fall under 5.5.2.1 through 5.5.2.3 shall be treated as a chemical dust in accordance with NFPA 654.

N **5.5.2.5** Where the mixture contains both combustible and noncombustible materials, the combustible components shall be used as the basis for the mixture classification.

N **5.5.2.6*** Where components with different chemical compositions do not remain homogeneously mixed, the properties of the individual constituents shall be considered separately.

5.5.3* Representative Samples.

N **5.5.3.1** Samples collected from each location shall be representative of material used in the process or equipment or found on surfaces at that location.

N **5.5.3.2** Samples that could oxidize or degrade in the presence of air shall be maintained in suitable inert gas or vacuum packaging until tested.

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

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

Chapter 6 Performance-Based Design Option

6.1 General Requirements.

6.1.1 Retained Prescriptive Requirements. Portions of a facility designed in accordance with this chapter as an alternative for particular prescriptive requirements shall meet all other relevant prescriptive requirements in this standard.

• **6.1.2*** It shall be permitted to use performance-based alternative designs for a process or part of a process, specific material, or piece of equipment in lieu of the prescriptive requirements found in Chapter 9.

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

6.1.3.1* General. All applicable aspects of the design, including those described in 6.1.4.1 through 6.1.4.13, shall be documented in a format and content acceptable to the AHJ.

6.1.4* Document Requirements. Performance-based designs shall be documented to include all calculations, references, assumptions, and sources from which material characteristics and other data have been obtained, or on which the designer has relied for some material aspect of the design in accordance with 6.1.4.

6.1.4.1* Technical References and Resources. When requested by the AHJ, the AHJ shall be provided with sufficient documentation to support the validity, accuracy, relevance, and precision of the proposed methods. The engineering standards, calculation methods, and other forms of scientific information provided shall be appropriate for the particular application and methodologies used.

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

6.1.4.3 Performance Criteria. Performance criteria, with sources, shall be documented.

6.1.4.4 Occupant Characteristics. Assumptions about occupant characteristics shall be documented.

6.1.4.5 Design Fire and Explosion Scenarios. Descriptions of combustible dust fire and explosion design scenarios shall be documented.

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

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

6.1.4.8 Safety Factors. The safety factors utilized shall be documented.

6.1.4.9 Prescriptive Requirements. Retained prescriptive requirements shall be documented.

6.1.4.10 Modeling Features.

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

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

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

6.1.4.12 Performance Evaluation. The performance evaluation summary shall be documented.

6.1.4.13 Use of Performance-Based Design Option. Design proposals shall include documentation that provides anyone involved in the ownership or management of the building with notification of the following:

(1) Approval of the building, facilities, equipment or processes, in whole or in part, as a performance-based design with certain specified design criteria and assumptions
(2) Need for required re-evaluation and reapproval in cases of remodeling, modification, renovation, change in use, or change in established assumptions

6.1.5* 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.

6.1.6 Sources of Data.

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

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

6.1.7* 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 subject to the management of change provisions of Section 8.12.

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

6.1.7.2* Any variation from the design shall be acceptable to the AHJ.

6.2 Risk Component and Acceptability. The specified performance criteria of Section 6.3 and the specified fire and explosion scenarios of Section 6.4 shall be permitted to be modified by a documented risk assessment acceptable to the AHJ. The final performance criteria, fire scenarios, and explosion scenarios established for the performance-based design shall be documented.

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

6.3.1 Life Safety.

6.3.1.1* The life safety objectives of 4.2.1 with respect to a fire hazard shall be achieved if either of the following conditions 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 time necessary to effect complete evacuation.

6.3.1.2 The life safety objectives of 4.2.1 with respect to an explosion hazard shall be achieved if either of the following conditions is 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 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 time necessary to effect complete evacuation.

6.3.2 Structural Integrity. The structural integrity objectives embodied in 4.2.1 and 4.2.2 with respect to fire and explosion shall be achieved when no critical structural element of the building is damaged to the extent that it can no longer support its design load under all fire and explosion scenarios.

6.3.3 Mission Continuity. The mission continuity objectives of 4.2.2 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

6.3.4 Mitigation of Fire Spread and Explosions. When limitation of fire spread is to be achieved, all of the following criteria shall be demonstrated:

(1) Adjacent combustibles shall not attain their ignition temperature.
(2) Building design and housekeeping shall prevent combustibles from accumulating exterior to the enclosed process system to a concentration that is capable of supporting propagation.
(3) Particulate processing systems shall prevent fire or explosion from propagating from one process system to an adjacent process system or to the building interior.

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

(1) Internal pressures in the building or building compartment or equipment sufficient to threaten its structural integrity
(2) Extension of the flame front outside the building or building compartment or equipment of origin except where intentionally vented to a safe location
(3) Rupture of the building or building compartment or equipment of origin and the ejection of fragments that can constitute missile hazards

6.4* Design Scenarios.

6.4.1 Fire Scenarios.

6.4.1.1* Each fuel object in the building or building compartment or equipment of origin shall be considered for inclusion as a fire scenario.

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

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

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

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

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

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

6.4.2 Explosion Scenarios.

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

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

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

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

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

6.5 Evaluation of Proposed Design.

6.5.1* A proposed design's performance shall be assessed relative to each documented performance criterion as established in Section 6.2 or in Section 6.3 and in each documented fire and explosion scenario established for the design, with the assessment conducted through the use of appropriate calculation methods acceptable to the AHJ.

6.5.2 The designer shall establish numerical performance criteria for each of the documented performance objectives established for the design.

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

Chapter 7 Dust Hazards Analysis (DHA)

7.1* General Requirements.

Δ **7.1.1 Retroactivity.** The requirements of this chapter shall be applied retroactively in accordance with 7.1.1.1 and 7.1.1.2.

7.1.1.1* A DHA shall be completed for all new processes and facility compartments.

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7.1.1.2* For existing processes and facility compartments, a DHA shall be completed by September 7, 2020.

N **7.1.1.3** The owner/operator shall demonstrate reasonable progress each year in completing DHAs prior to the deadline set in 7.1.1.2.

N **7.1.2** The owner/operator of a facility where materials determined to be combustible or explosible in accordance with Chapter 5 are present in an enclosure shall be responsible to ensure a DHA is completed in accordance with the requirements of this chapter.

7.1.3 The absence of previous incidents shall not be used as the basis for not performing a DHA.

N **7.1.4** The DHA shall be reviewed and updated at least every 5 years.

7.2 Criteria.

7.2.1* Overview. The DHA shall evaluate the fire, deflagration, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.2.

7.2.2* Qualifications. The DHA shall be performed or led by a qualified person.

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

7.3 Methodology.

7.3.1 General. The DHA shall include the following:

(1) Identification and evaluation of the process or facility areas where fire, flash fire, and explosion hazards exist
(2) Where such a hazard exists, identification and evaluation of specific fire and deflagration scenarios shall include the following:
    (a) Identification of safe operating ranges
    (b)* Identification of the safeguards that are in place to manage fire, deflagration, and explosion events
    (c) Recommendation of additional safeguards where warranted, including a plan for implementation

7.3.2 Material Evaluation.

7.3.2.1 The DHA shall be based on data obtained in accordance with Chapter 5 for material that is representative of the dust present.

7.3.3 Process Systems.

7.3.3.1* Each part of the process system where combustible dust is present or where combustible particulate solids could cause combustible dust to be present shall be evaluated, and the evaluation shall address the following:

(1) Potential intended and unintended combustible dust transport between parts of the process system
(2) Potential fugitive combustible dust emissions into a building or building compartments
(3) Potential deflagration propagation between parts of the process system

7.3.3.2 Each part of the process that contains a combustible particulate solid and that can potentially include both of the following conditions shall be considered a fire hazard and shall be documented as such:

(1) Oxidizing atmosphere
(2) Credible ignition source

7.3.3.3* Each part of the process that contains a sufficient quantity of combustible dust to propagate a deflagration and that can potentially include all the following conditions shall be considered a dust deflagration hazard and shall be documented as such:

(1) Oxidizing atmosphere
(2) Credible ignition source
(3) Credible suspension mechanism

7.3.4 Building or Building Compartments.

7.3.4.1 Each building or building compartment where combustible dust is present shall be evaluated.

7.3.4.1.1 Where multiple buildings or building compartments present essentially the same hazard, a single evaluation shall be permitted to be conducted as representative of all similar buildings or building compartments.

7.3.4.1.2 The evaluation shall address potential combustible dust migration between buildings or building compartments.

7.3.4.1.3 The evaluation shall address potential deflagration propagation between buildings or building compartments.

7.3.4.2* Each building or building compartment that contains a combustible particulate solid and that can potentially include both of the following conditions shall be considered a fire hazard and shall be documented as such:

(1) Oxidizing atmosphere
(2) Credible ignition source

7.3.4.2.1* The evaluation of dust deflagration hazard in a building or building compartment shall include a comparison of actual or intended dust accumulation to the threshold housekeeping dust accumulation that would present a potential for flash-fire exposure to personnel or compartment failure due to explosive overpressure.

7.3.4.2.2 Threshold housekeeping dust accumulation levels and nonroutine dust accumulation levels (e.g., from a process upset) shall be in accordance with relevant industry- or commodity-specific NFPA standards.

7.3.4.3 Each building or building compartment that contains a sufficient quantity of combustible dust to propagate a deflagration and that can potentially include all of the following conditions shall be considered a dust deflagration hazard and shall be documented as such:

(1) Oxidizing atmosphere
(2) Credible ignition source
(3) Credible suspension mechanism

Chapter 8 Management Systems

8.1 Retroactivity. This chapter shall be applied retroactively to new and existing facilities and processes.

8.2* General. The procedures and training in this chapter shall be delivered in a language that the participants can understand.

8.3 Operating Procedures and Practices.

8.3.1* The owner/operator shall establish written procedures for operating its facility and equipment to prevent or mitigate fires, deflagrations, and explosions from combustible particulate solids.

8.3.2* The owner/operator shall establish safe work practices to address hazards associated with maintenance and servicing operations.

8.3.2.1 The safe work practices shall apply to employees and contractors.

N **8.3.3** A periodic walk-through review of operating areas shall be conducted,on a schedule established by the owner/operator per the requirement in 8.7.3, to verify that operating procedures and safe work practices are being followed.

N **8.4 Housekeeping.**

N **8.4.1 General.**

N **8.4.2* Methodology.**

N **8.4.2.1 Procedure.**

N **8.4.2.1.1*** Housekeeping procedures shall be documented.

N **8.4.2.1.2*** The methods used for cleaning surfaces shall be selected on the basis of reducing the potential for creating a combustible dust cloud.

N **8.4.2.1.3** Cleaning methods to be used shall be based on the characteristics of the material and quantity of material present.

N **8.4.2.2 Vacuum Cleaning Method.**

N **8.4.2.2.1* Portable Vacuum Cleaners.**

N **8.4.2.2.1.1** Portable vacuum cleaners with a dirty side volume greater than 8 ft^3 shall comply with 9.7.3 and 9.7.4.

N **8.4.2.2.1.2*** When metal particles, dusts, or powders are being cleaned NFPA 484 shall be the reference source for proper use and limitations of both dry and wet portable vacuum cleaners.

N **8.4.2.2.1.3*** The operation of portable vacuum cleaning devices shall be subject to a dust hazard analysis to ensure that the risk to personnel and facility operations from deflagrations is minimized.

N **8.4.2.2.1.4** Hoses and vacuum tools shall be appropriate for use and be static dissipative or conductive.

N **8.4.2.2.1.5** Portable vacuum cleaners shall not be used on processes generating hot embers or sparks.

N **8.4.2.2.1.6*** For portable vacuum cleaners used with combustible dusts having a minimum ignition energy less than 30 mJ, the path to ground shall be verified prior to use after each movement or new connection, or both.

N **8.4.2.2.1.7*** Portable vacuum cleaners that meet the following minimum requirements shall be permitted to be used to collect combustible particulate solids in unclassified (nonhazardous) areas:

(1) Materials of construction shall comply with 9.4.7.1.
(2) Hoses shall be conductive or static dissipative.
(3) All conductive components, including wands and attachments, shall be bonded and grounded.
(4) The fan or blower shall be on the clean side of the primary filtration media or wet separation chamber.
(5) Electrical motors shall not be located on the dirty side of the primary filtration media or wet separation chamber unless listed for Class II, Division 1 locations.
(6)* Where liquids or wet materials 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.

N **8.4.2.2.2*** In Class II electrically classified (hazardous) locations, electrically powered vacuum cleaners shall be listed for the purpose and location or shall be a fixed-pipe suction system with a remotely located exhauster and an AMS installed in conformance with Section 9.3, and they shall be suitable for the dust being collected.

N **8.4.2.2.3** Where flammable vapors or gases are present in Class II areas, vacuum cleaners shall be listed for both Class I and Class II hazardous locations.

N **8.4.2.3* Sweeping, Shoveling, Scoop, and Brush Cleaning Method.** The use of scoops, brooms, and brushes for sweeping and shoveling shall be a permitted cleaning method.

N **8.4.2.4* Water Washdown Cleaning Method.**

N **8.4.2.4.1** The use of water washdown shall be a permitted cleaning method.

N **8.4.2.4.2** Where the combustible dust being removed is metal or metal-containing dust or powder within the scope of NFPA 484, the requirements of NFPA 484 shall be followed.

N **8.4.2.4.3*** Where the combustible dust being removed is a water-reactive material, additional precautions shall be taken to control the associated hazards.

N **8.4.2.5 Water Foam Washdown Systems. (Reserved)**

N **8.4.2.6 Compressed Air Blowdown Method.**

N **8.4.2.6.1*** Blowdowns using compressed air shall be permitted to be used as a cleaning method in accordance with the provisions of 8.4.2.6.2.

N **8.4.2.6.2*** Where blowdown using compressed air is used, the following precautions shall be followed:

(1) Prior to using compressed air, vacuum cleaning, sweeping, or water washdown methods are used to clean surfaces that can be safely accessed.
(2) Dust accumulations in the area after vacuum cleaning, sweeping, or water washdown do not exceed the threshold housekeeping dust accumulation.
(3) Compressed air hoses are equipped with pressure relief nozzles limiting the discharge pressure to 30 psi (207 kPa) in accordance with OSHA requirements in 29 CFR 1910.242(b), "Hand and Portable Powered Tools and Equipment, General."
(4) All electrical equipment, including lighting, potentially exposed to airborne dust in the area during cleaning is suitable for use in a Class II, Division 2, hazardous (classified) location in accordance with *NFPA 70*.
(5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.
(6) After blowdown is complete, residual dust on lower surfaces is cleaned prior to re-introduction of potential ignition sources.
(7) Where metal or metal-containing dust or powder under the scope of NFPA 484 is present, the requirements of NFPA 484 apply.

N **8.4.2.7 Steam Blow Down Method. (Reserved)**

N **8.4.3 Training.** Employee and contractor training shall include housekeeping procedures, required personal protective equipment (PPE) during housekeeping, and proper use of equipment.

N **8.4.4 Equipment. (Reserved)**

N **8.4.5 Vacuum Trucks.**

N **8.4.5.1** Vacuum trucks shall be grounded and bonded.

N **8.4.5.2** Vacuum truck hoses and couplings shall be static dissipative or conductive and grounded.

N **8.4.6 Frequency and Goal.**

N **8.4.6.1*** Housekeeping frequency and accumulation goals shall be established to ensure that the accumulated fugitive dust levels on surfaces do not exceed the threshold housekeeping dust accumulation limits.

N **8.4.6.2** The threshold housekeeping dust accumulation limits shall be in accordance with the industry- or commodity-specific NFPA standard. *(See 1.3.1.)*

N **8.4.6.3*** Provisions for unscheduled housekeeping shall include specific requirements establishing time to clean local dust spills or transient releases.

N **8.4.7 Auditing and Documentation.**

N **8.4.7.1*** Housekeeping effectiveness shall be assessed based on the results of routine scheduled cleaning and inspection, not including transient releases.

N **8.4.7.2** The owner/operator shall retain documentation that routine scheduled cleaning occurs in accordance with the frequency and accumulation goals established in 8.4.6.1.

N **8.5 Hot Work.**

N **8.5.1*** In addition to the requirements of NFPA 51B, all hot work activities shall comply with the requirements in 8.5.2 through 8.5.5.

N **8.5.2*** The area affected by hot work shall be thoroughly cleaned of combustible dust prior to commencing any hot work.

N **8.5.3** Equipment that contains combustible dust and is located within the hot work area shall be shut down, shielded, or both.

N **8.5.4** When the hot work poses an ignition risk to the combustible dust within equipment, the equipment shall be shut down and cleaned prior to commencing such hot work.

N **8.5.5** Floor and wall openings within the hot work area shall be covered or sealed.

N **8.5.6** Use of portable electrical equipment that does not comply with the electrical classification of the area where it is to be used shall be authorized and controlled in accordance with the hot work procedure as outlined in Section 8.5.

N **8.6 Personal Protective Equipment.**

N **8.6.1 Workplace Hazard Assessment.**

N **8.6.1.1*** An assessment of workplace hazards shall be conducted as described in NFPA 2113.

N **8.6.1.2** When the assessment in 8.6.1.1 has determined that flame-resistant garments are needed, personnel shall be provided with and wear flame-resistant garments.

N **8.6.1.3*** When flame-resistant clothing is required for protecting personnel from flash fires, it shall comply with the requirements of NFPA 2112.

N **8.6.1.4*** 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

N **8.6.1.5** Flame-resistant garments shall be selected, procured, inspected, worn, and maintained in accordance with NFPA 2113.

N **8.6.1.6*** The employer shall implement a policy regarding care, cleaning, and maintenance for flame-resistant garments.

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

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

N **8.6.2.2*** When determined by 8.6.1.1 that flame-resistant garments are needed, only flame-resistant outerwear shall be worn over flame-resistant daily wear.

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

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

8.7 Inspection, Testing, and Maintenance.

8.7.1* Equipment affecting the prevention, control, and mitigation of combustible dust fires, deflagrations, and explosions shall be inspected and tested in accordance with the applicable NFPA standard and the manufacturers' recommendations.

8.7.2 The inspection, testing, and maintenance program shall include the following:

(1) Fire and explosion protection and prevention equipment in accordance with the applicable NFPA standards
(2) Dust control equipment
(3) Housekeeping
(4) Potential ignition sources
(5)* Electrical, process, and mechanical equipment, including process interlocks
(6) Process changes
(7) Lubrication of bearings

8.7.3 The owner/operator shall establish procedures and schedules for maintaining safe operating conditions for its facility and equipment in regard to the prevention, control, and mitigation of combustible dust fires and explosions.

8.7.4* Where equipment deficiencies that affect the prevention, control, and mitigation of dust fires, deflagrations, and explosions are identified or become known, the owner/operator shall establish and implement a corrective action plan with an explicit deadline.

8.7.5* Inspections and testing activities that affect the prevention, control, and mitigation of dust fires, deflagrations, and explosions shall be documented.

Δ **8.7.6** A periodic walk-through review of operating areas shall be conducted, on a schedule established by the owner/operator per the requirement in 8.7.3, to verify that the equipment is in safe operating condition.

8.8 Training and Hazard Awareness.

8.8.1* 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.

8.8.2* General safety training and hazard awareness training for combustible dusts and solids shall be provided to all affected employees.

8.8.2.1* Job-specific training shall ensure that employees are knowledgeable about fire and explosion hazards of combustible dusts and particulate solids in their work environment.

8.8.2.2 Employees shall be trained before taking responsibility for a task.

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

8.8.3 Refresher training shall be provided as required by the AHJ and as required by other relevant industry- or commodity-specific NFPA standards.

8.8.4 The training shall be documented.

8.9 Contractors.

8.9.1 Owner/operators shall ensure the requirements of Section 8.9 are met.

8.9.2* Only qualified contractors shall be employed for work involving the installation, repair, or modification of buildings (interior and exterior), machinery, and fire and explosion protection equipment that could adversely affect the prevention, control, or mitigation of fires and explosions.

8.9.3* Contractor Training.

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

8.9.3.2 Contractor training shall be documented.

8.9.3.3* Contractors working on or near a given process shall be made aware of the potential hazards from and exposures to fires and explosions.

8.9.3.4 Contractors shall be trained and required to comply with the facility's safe work practices and policies in accordance with 8.3.2.

8.9.3.5 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.

8.10 Emergency Planning and Response.

8.10.1* A written emergency response plan shall be developed for preparing for and responding to work-related emergencies including, but not limited to, fire and explosion.

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

8.11* Incident Investigation.

8.11.1* The owner/operator shall have a system to ensure that incidents that result in a fire, deflagration, or explosion are reported and investigated in a timely manner.

8.11.2 The investigation shall be documented and include findings and recommendations.

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

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

8.12 Management of Change.

8.12.1* Written procedures shall be established and implemented to manage proposed changes to process materials, staffing, job tasks, technology, equipment, procedures, and facilities.

8.12.2 The procedures shall ensure that the following are addressed prior to any change:

(1)* The basis for the proposed change
(2)* Safety and health implications
(3) Whether the change is permanent or temporary, including the authorized duration of temporary changes
(4) Modifications to operating and maintenance procedures
(5) Employee training requirements
(6) Authorization requirements for the proposed change
(7) Results of characterization tests used to assess the hazard, if conducted

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

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

8.13* Documentation Retention.

8.13.1 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) Dust hazards analyses
(5)* Process and technology information
(6)* Management of change documents
(7) Emergency response plan documents
(8)* Contractor records

8.14 Management Systems Review.

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

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

8.15* Employee Participation. Owner/operators shall establish and implement a system to consult with and actively involve affected personnel and their representatives in the implementation of this standard.

Chapter 9 Hazard Management: Mitigation and Prevention

9.1* Inherently Safer Designs.

9.2 Building Design.

9.2.1 Risk Assessment. A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of building design and protection features to be provided, including, but not limited to, the measures addressed in Section 9.2.

9.2.2* Construction. The type of construction shall be in accordance with the building code adopted by the AHJ.

9.2.3 Building or Building Compartment Protection.

9.2.3.1* Each building or building compartment where a dust deflagration hazard exists shall be protected from the consequence of deflagration.

9.2.3.2* If a building or building compartment contains a dust explosion hazard outside of equipment, such areas shall be provided with deflagration venting to a safe area in accordance with NFPA 68.

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

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

9.2.4 Life Safety. Building configuration and appurtenances shall comply with the life safety requirements of the building and fire prevention codes adopted by the AHJ.

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

9.2.4.2 Where a dust explosion hazard exists in a building or building compartment and an enclosed means of egress is provided, it shall be designed to withstand potential external overpressure from building deflagration.

9.2.5 Construction Features to Limit Accumulation.

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

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

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

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

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

9.2.6.2 Use of Segregation.

9.2.6.2.1 Physical barriers erected for the purpose of limiting fire spread shall be designed in accordance with NFPA 221.

9.2.6.2.2 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.

9.2.6.2.3 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.

9.2.6.3 Use of Separation.

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

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

(1) Properties of the materials
(2) Type of operation
(3) Amount of material likely to be present outside the process equipment
(4) Building and equipment design
(5) Nature of surrounding exposures

9.2.6.3.3 Either the separation area shall be free of dust or where dust accumulations exist on any surface, the color of the surface on which the dust has accumulated shall be readily discernible.

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

9.2.6.3.5* Where 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.

9.2.6.4 Use of Detachment.

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

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

(1) Properties of the materials
(2) Type of operation
(3) Amount of material likely to be present outside the process equipment
(4) Building and equipment design
(5) Nature of surrounding exposures

9.3 Equipment Design.

9.3.1* Risk Assessment. A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of protection to be provided, including, but not limited to, protection measures addressed in Section 9.3.

9.3.2 Design for Dust Containment.

9.3.2.1 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.

9.3.2.2 Where the equipment cannot be designed for dust containment, dust collection shall be provided. *(See also 9.3.3.)*

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

9.3.3.1 General Requirements.

9.3.3.1.1* 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.

9.3.3.1.2* Where it is necessary to make changes to an existing system, all changes shall be managed in accordance with the management of change requirements in Section 8.12.

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

N **9.3.3.1.4 Systems That Convey Hybrid Mixtures.** The percentage of the lower flammable limit (LFL) of flammable vapors and the percentage of the minimum explosible concentration (MEC) of combustible dusts, when combined, shall not exceed 25 percent within the airstream, except for systems protected in accordance with 9.7.3.2(1) through 9.7.3.2(6).

9.3.3.1.5* Operations.

9.3.3.1.5.1 Sequence of Operation. Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed with the operating logic, sequencing, and timing outlined in 9.3.3.1.5.2 and 9.3.3.1.5.3.

9.3.3.1.5.2* 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.

9.3.3.1.5.3 Shutdown.

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

(B) The requirements of 9.3.3.1.5.3(A) shall not apply during emergency shutdown of the process, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

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

9.3.3.2* Specific Requirements for Pneumatic Conveying Systems.

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

9.3.3.2.2* 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.

9.3.3.2.3* Pneumatic conveying systems conveying combustible particulate solids and posing an explosion hazard shall be protected in accordance with Section 9.7.

9.3.3.3* Specific Requirements for Dust Collection Systems.

9.3.3.3.1* At each collection point, the system shall be designed to achieve the minimum velocity required for capture, control, and containment of the dust source.

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

9.3.3.3.3* 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.

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

9.3.3.3.5* Dust collection systems that remove material from operations that generate flames, sparks, or hot material under normal operating conditions shall not be interconnected with dust collection systems that transport combustible particulate solids or hybrid mixtures. *(See 9.7.4.)*

9.3.3.3.6* 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.

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

9.3.3.3.8* Control equipment controlling the operation of the AMS shall be installed in a location that is safe from the effects of a deflagration in the AMS.

9.3.3.4* Specific Requirements for Centralized Vacuum Cleaning Systems.

9.3.3.4.1* 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.

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

9.3.3.4.3* Where ignition-sensitive materials are collected, vacuum tools shall be constructed of metal or static dissipative materials and provide proper grounding to the hose.

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

 Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. *N* = New material.

9.3.4 AMS.

9.3.4.1 AMS Indoor Locations.

9.3.4.1.1* Dry AMS.

9.3.4.1.1.1 If the dirty side volume of the air-material separator is greater than 8 ft^3 (0.2 m^3), it shall be protected in accordance with Section 9.7.

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

9.3.4.1.2 Wet AMS.

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

(1) Interlocks are provided to shutdown the system if the flow rate of the scrubbing medium is less than the designed minimum flow rate.
(2) The scrubbing medium is not a flammable or combustible liquid.
(3) The separator is designed to prevent the formation of a combustible dust cloud within the air-material separator.
(4) The design of the separator addresses any reaction between the separated material and the scrubbing medium.

9.3.4.2 AMS Outdoor Locations. (Reserved)

9.3.4.3 AMS Clean Air Exhaust.

9.3.4.3.1 Exhaust air from the final AMS shall be discharged outside of buildings to a restricted area separated from clean air intakes for the building.

9.3.4.3.2* Air from AMSs shall be permitted to be recirculated directly back to the pneumatic conveying system.

9.3.4.3.3* Recycling of AMS exhaust to buildings or building compartments shall be permitted when all the following conditions are met:

(1) Combustible or flammable gases or vapors are not present in either the intake or the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the lower flammable limit (LFL), whichever is lower.
(2)* Combustible particulate solids are not present in the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the minimum explosible concentration (MEC), whichever is lower.
(3)* The oxygen concentration of the recycled air stream is between 19.5 percent and 23.5 percent by volume.
(4) Provisions are incorporated to prevent transmission of flame and pressure effects from a deflagration in an AMS back to the facility unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.
(5) Provisions are incorporated to prevent transmission of smoke and flame from a fire in an AMS back to the facility unless a DHA indicates that those effects do not pose a threat to the facility or the occupants.
(6) The system includes a method for detecting AMS malfunctions that would reduce collection efficiency and allow increases in the amount of combustible particulate solids returned to the building.
(7) The building or building compartment to which the recycled air is returned meets the requirements of Section 8.4.
(8) Recycled-air ducts are inspected and cleaned at least annually.

N **9.3.4.4 AMS Construction.**

N **9.3.4.4.1** AMSs shall be constructed of noncombustible materials.

N **9.3.4.4.2** Filter media and filter media support frames shall be permitted to be constructed of combustible material.

N **9.3.4.4.3** Where isolated from an AMS by a valve, portable containers intended to receive materials discharged from the AMS shall be permitted to be constructed of combustible material.

N **9.3.4.4.4** AMSs shall be constructed to minimize internal ledges or other points of dust accumulation.

N **9.3.4.4.5** Hopper bottoms shall be sloped and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

N **9.3.4.4.6** Where provided to permit inspection, cleaning, and maintenance, access doors and access openings shall meet the following requirements:

(1) They shall be designed to prevent dust leaks.
(2) They shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.
(3) They shall be bonded and grounded.
(4)* If not designed to be used as deflagration vents, they shall be designed to the same strength as the AMS.

N **9.3.5 Air-Moving Devices (Fans and Blowers).**

N **9.3.5.1** Air-moving devices (AMDs) shall conform to the requirements of NFPA 91, except as amended by the requirements of this chapter.

N **9.3.5.2** Where an explosion hazard exists, systems shall be designed in such a manner that combustible particulate solids do not pass through an AMD.

N **9.3.5.3*** The requirement of 9.3.5.2 shall not apply to systems protected by an approved explosion prevention or isolation system to prevent the propagation of the flame front from the fan to other equipment in accordance with 9.7.3.2(1), 9.7.3.2(5), 9.7.3.2(6), or 9.7.4.

N **9.3.5.4*** Where an AMD is located in the dirty air stream and the dust/air stream concentration is higher than 10 percent of the MEC, fans and blowers shall be of Type A or Type B spark-resistant construction per AMCA 99-0401-86, *Classification for Spark Resistant Construction*, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan.

N **9.3.6 Duct Systems.**

N **9.3.6.1** Ducts that handle combustible particulate solids shall conform to the requirements of NFPA 91, except as amended by the requirements of this chapter.

N **9.3.6.2*** Changes in duct sizes shall be designed to prevent the accumulation of material by utilizing a tapered transformation piece, with the included angle of the taper not more than 30 degrees.

N **9.3.6.3*** When ducts pass through a physical barrier erected to segregate dust deflagration hazards, physical isolation protection shall be provided to prevent propagation of deflagrations between segregated spaces.

N **9.3.6.3.1** Access doors, openings, or removable sections of ductwork shall be provided to allow inspection, cleaning, maintenance, and fire department access.

N **9.3.6.3.2** Access doors, openings, or removable sections of ductwork shall be designed and maintained to prevent dust leaks and preserve the integrity of the duct.

N **9.3.6.3.3** Access doors, openings, or removable sections of ductwork that are not specifically designed for deflagration venting shall not be considered as providing that function.

N **9.3.6.3.4** Access doors, openings, or removable sections of ductwork shall be bonded and grounded.

N **9.3.7 Sight Glasses.**

N **9.3.7.1** Sight glasses shall be of a material that is impact and erosion-resistant.

N **9.3.7.2** Sight glass assemblies shall have a pressure rating equal to or greater than that of the ductwork.

N **9.3.7.3** Ductwork shall be supported on each side of the sight glass so that the sight glass does not carry any of the system weight and is not subject to stress or strain.

N **9.3.7.4** The mechanical strength of the sight glass–mounting mechanism shall be equal to the adjoining ductwork.

N **9.3.7.5** The inside diameter of a sight glass shall not cause a restriction of flow.

N **9.3.7.6** The connections between the sight glass and the ductwork shall be squarely butted and sealed so as to be both airtight and dusttight.

N **9.3.7.7** The electrical bonding across the length of the sight glass shall be continuous and have a resistance of no more than 1 ohm.

N **9.3.8 Abort Gates/Dampers.**

N **9.3.8.1 Construction.**

N **9.3.8.1.1** Abort gates and abort dampers shall be constructed of noncombustible materials.

N **9.3.8.1.2** Abort gates and abort dampers shall be actuated by spark detection or equivalent automatic detection in the duct or pipe upstream of the device.

N **9.3.8.1.3** The detection system and abort gate shall respond to prevent sparks, glowing embers, or burning materials from passing beyond the abort gate.

N **9.3.8.1.4** The abort gate or abort damper shall be installed so that it diverts airflow to a restricted area to safely discharge combustion gases, flames, burning solids, or process gases or fumes.

N **9.3.8.2 Manual Reset.**

N **9.3.8.2.1** An abort gate or abort damper shall be provided with a manually activated reset located proximate to the device such that, subsequent to operation, it can be returned to the normal operating position at the damper/gate.

N **9.3.8.2.2** Automatic or remote reset provisions shall not be permitted.

N **9.3.8.3 Integrity of Actuation Circuits.**

N **9.3.8.3.1** All fire protection abort gates or abort dampers shall be connected to the fire detection control panel via Class A or Class D circuits as described in *NFPA 72*.

N **9.3.8.3.2** When the abort gate is connected via a Class A circuit, supervision shall include the continuity of the abort gate or abort damper releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device.

N **9.3.9 Bulk Storage Enclosures.**

N **9.3.9.1 General.**

N **9.3.9.1.1** For the purposes of this section, bulk storage enclosures shall include items such as bins, tanks, hoppers, and silos.

N **9.3.9.1.2*** The requirements of this section shall not apply to containers that are used for transportation of the material.

N **9.3.9.2* Construction.** Bulk storage enclosures, whether located inside or outside of buildings, shall be constructed so as not to represent an increase in the fire load beyond the capabilities of the existing fire protection.

N **9.3.9.3 Fixed Bulk Storage Location.**

N **9.3.9.3.1** Where an explosion hazard exists, fixed bulk storage enclosures shall be located outside of buildings.

N **9.3.9.3.2** Fixed bulk storage enclosures shall be permitted to be located inside buildings where one of the following applies:

(1) Fixed bulk storage enclosures are protected in accordance with 9.7.3.
(2)* Fixed bulk storage enclosures are less than 8 ft^3 (0.2 m^3).

N **9.3.9.4* Interior Surfaces.** Interior surfaces shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulation.

N **9.3.9.5 Access Doors and Access Openings.** Where provided to permit inspection, cleaning, and maintenance, access doors and access openings shall meet the following requirements:

(1) They shall be designed to prevent dust leaks.
(2) They shall be permitted to be used as deflagration vents if they are specifically designed for both purposes.
(3) They shall be bonded and grounded.
(4) If not designed to be used as deflagration vents, they shall be designed to the same strength as the AMS.

N **9.3.10* Size Reduction.** Before material is processed by size reduction equipment, foreign materials shall be excluded or removed as required by 9.4.12.

N **9.3.11* Particle Size Separation.**

N **9.3.11.1** Particle separation devices shall be designed to control fugitive dust emissions per Section 9.6.

N **9.3.11.2** Flexible connectors shall be in conformance with 9.3.6.

N **9.3.12 Pressure Protection Systems.**

N **9.3.12.1 Vacuum Breakers.** Vacuum breakers shall be installed on negative-pressure systems if the enclosure is not designed for the maximum vacuum attainable.

N **9.3.12.2 Pressure Relief Devices.**

N **9.3.12.2.1** Pressure relief devices for relief of pneumatic overpressure shall be installed on positive-pressure systems.

N **9.3.12.2.2** The requirement of 9.3.12.2.1 shall not apply to systems that are designed for a gauge pressure of less than 15 psi (103 kPa) and are provided with safety interlocks designed to prevent overpressure in accordance with ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector*.

N **9.3.12.2.3** The requirement of 9.3.12.2.1 shall not apply to systems that are designed for a gauge pressure of less than 15 psi (103 kPa) and are capable of containing the maximum pressure attainable.

N **9.3.12.2.4*** Pressure relief devices shall not be vented to an area where a dust explosion hazard or dust flash-fire hazard exists in accordance with 7.3.4.

N **9.3.12.3 Airflow Control Valves.**

N **9.3.12.3.1** Airflow control valves that are installed in pneumatic conveying, dust collection, or centralized vacuum cleaning systems shall provide a tight shutoff.

N **9.3.12.3.2** Airflow control valves shall be sized to allow passage of the design airflow when the valve is fully open.

N **9.3.12.3.3** The position of airflow control valves shall be visually indicated.

N **9.3.12.3.4** Manually adjusted airflow control valves, dampers, or gates, shall have a means of being secured so as to prevent subsequent adjustment or manipulation once the system is set.

N **9.3.12.3.5** Diverter valves shall effect a positive diversion of the material and shall mechanically seal all other directions from air or material leakage.

N **9.3.13 Material Feeding Devices.**

N **9.3.13.1 Mechanical Feeding Devices.**

N **9.3.13.1.1** Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm.

N **9.3.13.1.2** The alarm shall sound at the operator control station.

N **9.3.13.2 Drives.**

N **9.3.13.2.1** All drives used in conjunction with feeders, air locks, and other material feeding devices shall be directly connected.

N **9.3.13.2.2** Belt, chain and sprocket, or other indirect drives that are designed to stall the driving forces without slipping and to provide for the removal of static electric charges shall be permitted to be used.

N **9.3.14* Bucket Elevators.**

N **9.3.14.1** Elevator casings, head and boot sections, and connecting ducts shall be designed to control fugitive dust emissions and shall be constructed of noncombustible materials.

N **9.3.14.2** Where provided, inlet and discharge hoppers shall be designed to be accessible for cleaning and inspection.

N **9.3.14.3 Power Cutoff.**

N **9.3.14.3.1** Each leg shall be provided with a speed sensor device that will cut off the power to the drive motor and actuate an alarm in the event the leg belt slows to 80 percent of normal operating speed.

N **9.3.14.3.2** Feed to the elevator leg by mechanical means shall be stopped or diverted.

N **9.3.14.4 Belts.**

N **9.3.14.4.1*** Belt-driven bucket elevators shall have nonslip material (lagging) installed on the head pulley to minimize slippage.

N **9.3.14.4.2*** Belts and lagging shall be static dissipative and fire resistant.

N **9.3.14.4.3** No bearings shall be located in the bucket elevator casing.

N **9.3.14.4.4*** Head and boot sections shall be provided with openings to allow for cleanout, inspection, and alignment of the pulley and belt.

N **9.3.14.5 Drive.**

N **9.3.14.5.1*** The bucket elevator shall be driven by a motor and drive train that is capable of handling the full-rated capacity of the elevator without overloading.

N **9.3.14.5.2** The drive shall be capable of starting the unchoked elevator under full (100 percent) load.

N **9.3.14.6 Monitors.**

N **9.3.14.6.1** Elevators shall have monitors at head and tail pulleys that indicate high bearing temperature, pulley alignment, and belt alignment.

N **9.3.14.6.2** Abnormal conditions shall actuate an alarm requiring corrective action.

N **9.3.14.6.3** The alarm specified in 9.3.14.6.2 shall sound at the operator control station.

N **9.3.14.7 Emergency Controls.**

N **9.3.14.7.1** All bins into which material is directly discharged from the bucket elevator and that are not designed with automatic overflow systems shall be equipped with devices to shut down equipment or with high-level indicating devices with visual or audible alarms.

N **9.3.14.7.2** The audible alarm specified in 9.3.14.7.1 shall sound at the operator control station.

N **9.3.15* Enclosed Conveyors.**

N **9.3.15.1 Housing and Coverings.**

N **9.3.15.1.1** Housings for enclosed conveyors (e.g., screw conveyors and drag conveyors) shall be of metal construction and designed to prevent escape of combustible dusts.

N **9.3.15.1.1.1** Flexible screw conveyors utilizing nonmetal housing shall be permitted to be used, provided the requirements of 9.4.7.1.2 are met.

N **9.3.15.1.2** Coverings on cleanout, inspection, and other openings shall be fastened to prevent the escape of combustible dusts.

N **9.3.15.2 Power Shutoff.**

N **9.3.15.2.1*** All conveyors shall be equipped with a device that shuts off the power to the drive motor and sounds an alarm in the event the conveyor plugs.

N **9.3.15.2.2** The alarm specified in 9.3.15.2.1 shall alert operators, and feed to the conveyor shall be stopped or diverted.

N **9.3.16 Mixers and Blenders.**

N **9.3.16.1** Mixers and blenders shall be designed to control fugitive dust emissions.

N **9.3.16.2** Foreign materials shall be excluded or removed as required by 9.4.12.

N **9.3.16.3** Mixers and blenders shall be made of metal, other noncombustible material, or material that does not represent an increased fire load beyond the capabilities of the existing fire protection.

N **9.3.17* Dryers.**

N **9.3.17.1 Drying Media.**

N **9.3.17.1.1** Drying media that come into contact with material being processed shall not be recycled to rooms or buildings.

N **9.3.17.1.2** Drying media shall be permitted to be recycled to the drying process provided the following conditions are met:

(1) The media passes through a filter, dust separator, or equivalent means of dust removal.
(2) The vapor flammability of the drying media in the dryer is controlled by either oxidant concentration reduction or combustible concentration reduction in accordance with NFPA 69.

N **9.3.17.1.3** Dryers shall be constructed of noncombustible materials.

N **9.3.17.1.4** Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated.

N **9.3.17.1.5** Access doors or openings shall be provided in all parts of the dryer and connecting conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams.

N **9.3.17.1.6** Heated dryers shall comply with NFPA 86.

N **9.3.17.1.7*** Heated dryers shall have operating controls arranged to maintain the temperature of the drying chamber within the prescribed limits.

N **9.3.17.1.8** Heated dryers and their auxiliary equipment shall be equipped with separate excess-temperature-limit controls, independent of the operating controls, arranged to supervise the following:

(1) Heated air supply to the drying chamber
(2) Airstream at the discharge of the drying chamber

9.3.18 Transfer Points. (Reserved)

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9.4 Ignition Source Control.

9.4.1* Retroactivity. Unless otherwise specified, the requirements of Section 9.4 shall be applied retroactively.

9.4.2* Risk Assessment. A documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of ignition source control to be provided including, but not limited to, the controls addressed in Section 9.4.

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N **9.4.3 Hot Work.** See Section 8.5.

9.4.4 Hot Surfaces.

9.4.4.1 Retroactivity. This section shall not be required to be applied retroactively.

9.4.4.2* Heated external surfaces of process equipment and piping in dust deflagration hazard areas shall be maintained at a temperature at least 112°F (50°C) below the dust layer and dust cloud ignition temperatures measured in a standardized test acceptable to the AHJ.

9.4.5 Bearings.

9.4.5.1 Retroactivity. This section shall not be required to be applied retroactively.

9.4.5.2* Bearings that are directly exposed to a combustible dust atmosphere or that are subject to dust accumulation, either of which poses a dust ignition hazard, shall be monitored for overheating.

9.4.5.3 The owner/operator shall establish frequencies for monitoring bearings in 9.4.5.2.

9.4.5.4* It shall be permitted to eliminate bearing monitoring based on a risk assessment acceptable to the AHJ.

9.4.6 Hazardous (Classified) Locations for Electrical Installations.

Δ **9.4.6.1*** The identification of the possible presence and extent of Class II and Class III locations shall be made based on the criteria in 500.5(C) and (D) of *NFPA 70*.

9.4.6.1.1* 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.

9.4.6.2 Electrical equipment and wiring within Class II locations shall comply with Article 502 of *NFPA 70*.

9.4.6.3 Electrical equipment and wiring within Class III locations shall comply with Article 503 of *NFPA 70*.

9.4.6.4* 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 visible dust accumulation.

9.4.6.5* Zone classification for dusts in accordance with Article 506 of *NFPA 70* shall not be permitted.

9.4.7* Electrostatic Discharges.

9.4.7.1 Conductive Equipment.

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

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

(1)* Hybrid mixtures and flammable gas/vapor atmospheres are not present.
(2)* Conductive particulate solids are not handled.
(3)* The nonconductive components do not result in isolation of conductive components from ground.
(4)* The breakdown strength across nonconductive sheets, coatings, or membranes does not exceed 4 kV, and the breakdown strength across nonconductive woven objects does not exceed 6 kV, when used in high surface charging processes.

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

9.4.7.1.4* Flexible Connectors.

9.4.7.1.4.1* Retroactivity. This section shall not be required to be applied retroactively.

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

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

(1) The dust has an MIE greater than 2000 mJ.
(2) The maximum powder transfer velocity is less than 2000 fpm (10 m/sec).

9.4.7.2 Maximum Particulate Transport Rates.

Δ **9.4.7.2.1*** The maximum particulate transport rates in 9.4.7.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft^3 (1 m^3) and a single feed stream to the vessel meets both of the following conditions:

(1)* The suspendable fraction of the transported material has an MIE of less than or equal to 20 mJ.
(2)* The transported material has an electrical volume resistivity greater than 1.0×10^{10} ohm-m.

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

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

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

(1) 3.1 lb/sec (1.4 kg/sec) for particulates larger than 0.08 in. (2 mm).
(2) 12.3 lb/sec (5.6 kg/sec) for particulates between 0.016 in. (0.4 mm) and 0.08 in. (2 mm) in size.
(3) 18.3 lb/sec (8.3 kg/sec) for particulates smaller than 0.016 in. (0.4 mm).

9.4.7.3* Grounding of Personnel.

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

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

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

9.4.7.4* Flexible Intermediate Bulk Containers (FIBCs). FIBCs shall be permitted to be used for the handling and storage of combustible particulate solids in accordance with the requirements in 9.4.7.4.1 through 9.4.7.4.7.

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

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

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

9.4.7.4.2.2* Type A FIBCs shall not be used with conductive dusts.

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

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

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

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

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

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

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

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

9.4.7.4.5.1* Type D FIBCs shall not be permitted to be used for conductive particulate solids.

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

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

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

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

Δ **9.4.7.4.6.4** FIBCs that have not been tested and verified for type in accordance with IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, shall not be used for combustible dusts or in flammable vapor atmospheres.

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

9.4.7.5 Rigid Intermediate Bulk Containers (RIBCs).

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

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

9.4.8 Open Flames and Fuel-Fired Equipment.

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

9.4.8.2 Fuel-fired space heaters drawing local ambient air shall not be located within a Class II hazardous (classified) area.

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

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

9.4.8.4 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.

9.4.8.5 Unless the equipment is operated within the limits of 9.4.4.2, provisions shall be made to prevent the accumulation of combustible dust on heated surfaces of heating units.

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

9.4.9 Industrial Trucks.

9.4.9.1 Industrial trucks shall be listed or approved for the electrical classification of the area, as determined by 9.4.6, and shall be used in accordance with NFPA 505.

Δ **9.4.9.2*** Where industrial trucks in accordance with NFPA 505 are not commercially available, a documented risk assessment shall be permitted to be used to specify the fire and explosion prevention features for the equipment being used.

9.4.10 Process Air and Media Temperatures.

9.4.10.1* Heated process equipment containing combustible dust shall have operating controls arranged to maintain the temperature of equipment interiors within the prescribed limits.

9.4.11 Self-Heating.

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

9.4.11.2 Where a self-heating hazard is identified, provisions shall be in place for managing the consequences of self-heating in storage silos or bins.

9.4.12 Friction and Impact Sparks.

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

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

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

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

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

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9.5 Pyrophoric Dusts. (Reserved)

9.6 Dust Control.

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

9.6.1.1 Where continuous suction is used, the dust shall be conveyed to air–material separators designed in accordance with 9.3.2.

9.6.2* Liquid Dust Suppression Methods for Dust Control.

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

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

9.6.3* Fans for Continuous Dust Control. It shall be permitted to install and use fans to limit dust accumulation in elevated areas that are otherwise difficult to reach for housekeeping.

N **9.6.3.1** Fans shall be appropriate for the electrical classification in the areas where they are used.

N **9.6.3.2** Fans shall be provided in sufficient numbers and locations as required to keep the target areas free of dust accumulations.

N **9.6.3.3** Fans shall be in operation whenever the equipment generating the dusts is in operation.

N **9.6.3.4** Fans shall be interlocked to automatically shut down in the event of sprinkler system operation.

N **9.6.3.5** Dust dispersed by the fans shall not create an explosible dust cloud.

N **9.6.3.6** The location and range of motion of the fans shall be designed to prevent flow impingement on floors or open equipment containing entrainable dust.

N **9.6.3.7** Areas that will be swept by the fans shall be free of dust accumulations prior to placing the fans in operation and after every shutdown.

N **9.6.3.8*** These fans shall be used in conjunction with the housekeeping program to remove dust from the facility.

N **9.6.3.9*** Concealed spaces, such as areas above suspended ceilings, shall be sealed to prevent dust accumulation.

N **9.6.3.10** These systems shall not be used where areas above suspended ceilings are used as return air plenums for HVAC systems.

N **9.6.3.11** Periodic inspections shall be performed to ensure that dust accumulations are maintained below the threshold dust layer thicknesses determined in 8.4.6.

9.7 Explosion Prevention/Protection.

9.7.1 General. Where a dust explosion hazard exists within an enclosure, measures shall be taken as specified in Section 9.7 to protect personnel from the consequences of a deflagration in that enclosure.

9.7.2 Risk Assessment. A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of protection to be provided, including, but not limited to, the measures addressed in Section 9.7.

9.7.3 Equipment Protection.

Δ **9.7.3.1* General.** Where an explosion hazard exists within any operating equipment greater than 8 ft^3 (0.2 m^3) of containing volume, the equipment shall be protected from the effects of a deflagration.

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

(1) Oxidant concentration reduction in accordance with NFPA 69
(2) Deflagration venting in accordance with NFPA 68
(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

9.7.3.3 Enclosures and all interconnections protected in accordance with 9.7.3.2 shall be designed to withstand the resultant pressures produced during the deflagration event.

9.7.4* Equipment Isolation.

9.7.4.1 Where a dust explosion hazard exists, isolation devices shall be provided in accordance with NFPA 69 to prevent deflagration propagation between connected equipment.

• Δ **9.7.4.2** Isolation devices shall not be required where oxidant concentration has been reduced in accordance with 9.7.3.2(1) or where the dust has been rendered noncombustible in accordance with 9.7.3.2(6).

Δ **9.7.4.3** Where a dust explosion hazard exists, isolation devices shall be provided in accordance with NFPA 69 to prevent deflagration propagation from equipment through ductwork to the work areas.

9.8 Fire Protection.

9.8.1 General.

Δ **9.8.1.1** Where a fire hazard exists in an enclosure as determined in Chapter 7, manual or automatic fire protection means shall be provided in accordance with Section 9.8.

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

(1)* Manual fire fighting poses an unacceptable risk to facility personnel and emergency responders.
(2)* Manual fire fighting is not expected to be effective for a fire hazard assessed in accordance with Chapter 7.
(3) Automatic fire protection systems are required by the local building code adopted by the AHJ.

9.8.2 System Requirements. Fire protection systems where provided shall comply with 9.8.2.1 through 9.8.2.4.

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

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

9.8.2.3 Where fire-fighting water or wet product can accumulate in the system, the vessel, pipe supports, and drains shall be designed in accordance with NFPA 91.

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

9.8.3 Fire Extinguishers.

9.8.3.1 Portable fire extinguishers shall be provided throughout all buildings in accordance with the requirements of NFPA 10.

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

9.8.4 Hose, Standpipes, Hydrants, and Water Supply.

9.8.4.1 Standpipes and hose, where provided, shall comply with NFPA 14.

9.8.4.2 Nozzles.

9.8.4.2.1* 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.

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

9.8.4.2.3 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 9.8.4.2.1.

9.8.4.3 Water Supply.

9.8.4.3.1 Private hydrants and underground mains, where provided, shall comply with NFPA 24.

9.8.4.3.2 Fire pumps, where provided, shall comply with NFPA 20.

9.8.4.3.3 Fire protection water tanks, where provided, shall comply with NFPA 22.

9.8.5 Automatic Sprinklers.

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

9.8.5.2* Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled unless permitted by NFPA 484.

9.8.5.3 Automatic sprinklers, where provided, shall be installed in accordance with NFPA 13.

9.8.5.4 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.

9.8.6 Spark/Ember Detection and Extinguishing Systems. Where provided, spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 15, NFPA 69, and *NFPA 72*.

9.8.7 Special Fire Protection Systems.

9.8.7.1 Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards, as applicable:

(1) NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*
(2) NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*
(3) NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*
(4) NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*
(5) NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems*
(6) NFPA 17, *Standard for Dry Chemical Extinguishing Systems*
(7) NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*
(8) NFPA 750, *Standard on Water Mist Fire Protection Systems*
(9) NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*

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

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.

N **A.1.1** The scope statement uses the term *combustible dust* as it is defined in this document. In this definition, there is no upper limit for particle size for combustible dusts and no exclusion on nonspherical particles such as flakes, platelets, and fibers. The current edition of *NFPA 70 (NEC)* defines combustible dust in a more restrictive manner, focused on the necessary electrical equipment design requirements and limited to a maximum particle size of 500 microns. *NFPA 70* further excludes fibrous materials and flyings from its combustible dust definition. While a material might not be a combustible dust per the *NFPA 70* definition, it can present the same process and operational hazards as materials with fine particles.

N **A.1.3.3(4)** Warehousing includes the storage of bags, supersacks, or other containers of combustible dusts where no processing or handling of the dusts is performed except for moving closed containers or loaded pallets. If the business activity of the facility or specific areas of the facility are confined to strictly warehousing, then the standard does not apply. However, if the facility is processing or handling the dusts outside of the closed containers (e.g., opening containers and dispensing dusts), then the facility is required to meet all of the applicable requirements of this standard.

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

A.1.7.2 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 Air-Moving Device (AMD). An air-moving device is a fan or blower. A general description of each follows:

(1) Fans
   (a) A wide range of devices that utilize an impeller, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.
   (b) These devices are commonly used to create comparatively high air/gas volume flows at relatively low differential pressures.
   (c) These devices are typically used with ventilation and/or dust collection systems.
   (d) Examples are centrifugal fans, industrial fans, mixed or axial flow fans, and inline fans.
(2) Blowers
   (a) A wide range of devices that utilize various shaped rotating configurations, contained within a housing, that when rotated create air/gas flow by negative (vacuum) or positive differential pressure.
   (b) These devices are commonly used to create comparatively high differential pressures at comparatively low air/gas flows.
   (c) The most common use of these devices is with pneumatic transfer, high-velocity, low-volume (HVLV) dust collection and vacuum cleaning systems.
   (d) Examples are positive displacement (PD) blowers, screw compressors, multistage centrifugal compressors/blowers and regenerative blowers.

Δ **A.3.3.5 Centralized Vacuum Cleaning System.** This system normally consists of multiple hose connection stations hard-piped to an AMS located out of the hazardous area. Positive displacement or centrifugal AMDs can be used to provide the negative pressure air flow. The hoses and vacuum cleaning tools utilized with the system should be designed to be conductive or static-dissipative in order to minimize any risk of generating an ignition source. Low MIE materials should be given special consideration in the system design and use. A primary and secondary AMS separator combination (e.g., cyclone and filter receiver) can be used if large quantities of materials are involved. However, most filter receivers are capable of handling the high material loadings without the use of a cyclone.

Δ **A.3.3.6 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 (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., 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. Therefore, 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 ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, and a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, could be used to determine dust explosibility. Chapter 5 has additional information on testing requirements.

There is some possibility that a sample will result in a false positive in the 20 L sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source overdriving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale (≥1 m^3) enclosure, which is less susceptible to overdriving and thus will provide more realistic results.

This possibility for false positives has been known for quite some time and is attributed to "overdriven" conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m^3 chamber for most dusts. In fact, the U.S. standard for 20 L testing (ASTM E1226) states, "The objective of this test method is to develop data that can be correlated to those from the 1 m^3 chamber (described in ISO 6184-1 and VDI 3673)…" ASTM E1226 further states, "Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and P_{max} parameters are known in the 1 m^3 chamber."

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

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.

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, welding slag, frictional heat, or a flame

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

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 E1226, *Standard Test Method for Explosibility of Dust Clouds*
(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

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. Therefore, 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, which is nominally taken as 21 percent oxygen and 79 percent nitrogen, the applicable tests should be conducted in the appropriate process-specific medium.

A.3.3.7 Combustible Metal. See NFPA 484 for further information on determining the characteristics of metals.

Δ **A.3.3.8 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.

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

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

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

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

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

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

N **A.3.3.10 Conductive.** A typical threshold for solid materials of construction would be a volume resistivity less than 10^5 ohm-m.

A.3.3.11 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.

N **A.3.3.13 Dissipative.** Typically, a dissipative material is one having a surface resistivity between 10^5 ohms per square and 10^9 ohms per square or a volume resistivity between 10^5 ohm-m and 10^9 ohm-m. The intent is to limit the voltage achieved by electrostatic charge accumulation to a potential that is less than the threshold voltage for incendive discharge. Some applications might require different resistivities to accommodate different charging rates or desired relaxation times.

Δ **A.3.3.15 Dust Collection System.** A typical dust collection system consists of the following:

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

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

Δ **A.3.3.18 Dust Hazards Analysis (DHA).** In the context of this definition it is not intended that the dust hazards analysis (DHA) must comply with the process hazards analysis (PHA) requirements contained in OSHA regulation 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals." While the DHA can comply with OSHA PHA requirements, other methods can also be used *(see Annex B)*. However, some processes might fall within the scope of OSHA regulation 29 CFR 1910.119, and there could be a legal requirement to comply with that regulation.

A.3.3.19 Enclosure. Examples of enclosures include a room, building, vessel, silo, bin, pipe, or duct. [**68,** 2018]

N **A.3.3.20 Explosible.** For dusts, explosibility is determined as described in 5.4.3. For hybrid mixtures, see NFPA 68.

A.3.3.23 Flash Fire. A flash fire requires an ignition source and an atmosphere containing a flammable gas, a flammable vapor, or finely divided combustible particles (e.g., coal dust or grain) having a concentration sufficient to allow flame propagation. Flammable gas, flammable vapor, and dust flash fires typically generate temperatures from 1000°F to 1900°F (538°C to 1038°C). The extent and intensity of a flash fire depend on the size and concentration 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.

Δ **A.3.3.28 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. 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.3.3.29 Industry- or Commodity-Specific NFPA Standard. It is possible that within a single building or enclosure more than one industry- or commodity-specific NFPA standard could apply. The following documents are commonly recognized as commodity-specific standards:

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

Δ **A.3.3.30.1 Flexible Intermediate Bulk Container (FIBC).** FIBCs are usually made from nonconductive materials. Electrostatic charges that develop as FIBCs are filled or emptied can result in electrostatic discharges, which might pose an ignition hazard for combustible dust or flammable vapor atmospheres within or outside the bag. The four types of FIBCs — Type A, Type B, Type C, and Type D — are based on their characteristics for control of electrostatic discharges.

Δ **A.3.3.30.2 Rigid Intermediate Bulk Container (RIBC).** These are often called *composite IBCs*, which is the term used by the

U.S. Department of Transportation (DOT). The term *rigid nonmetallic intermediate bulk container* denotes an all-plastic single-wall IBC that might or might not have a separate plastic base and for which the containment vessel also serves as the support structure.

A.3.3.32 Minimum Explosible Concentration (MEC). Minimum explosible concentration is defined by the test procedure in ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*. MEC is equivalent to the lower flammable limit for flammable gases. Because it has been customary to limit the use of the lower flammable limit to flammable vapors and gases, an alternative term is necessary for combustible dusts.

The MEC is dependent on many factors, including particulate size distribution, chemistry, moisture content, and shape. Consequently, designers and operators of processes that handle combustible particulate solids should consider those factors when applying existing MEC data. Often, the necessary MEC data can be obtained only by testing.

Δ **A.3.3.33 Minimum Ignition Energy (MIE).** The standard test procedure for MIE of combustible particulate solids is ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, and the standard test procedure for MIE of flammable vapors is ASTM E582, *Standard Test Method for Minimum Ignition Energy and Quenching Distance in Gaseous Mixtures*.

N **A.3.3.34 Mixture.** Mixtures can pose unique hazard management challenges depending upon the constituents. For example, mixtures consisting of reactive metals mixed with plastics or cellulosic materials can lead to unexpected reactions when water or sodium bicarbonate is applied for fire or deflagration management. It is important to identify the predominant portion of the mixture in order to determine which industry or commodity specific standard applies.

N **A.3.3.35 Nonconductive.** Typically, a nonconductive material is one having a surface resistivity greater than 10^9 ohms per square or a volume resistivity greater than 10^9 ohm-m.

Δ **A.3.3.36 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)

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.

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.

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.

A.3.3.41 Risk Assessment. A risk assessment is a process that performs the following:

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

Steps 1 through 3 are typically performed as part of a dust hazards analysis (DHA).

Risk assessments can be qualitative, semiquantitative, or quantitative. Qualitative methods are usually used to identify the most hazardous events. Semiquantitative methods are used to determine relative hazards associated with unwanted events and are typified by indexing methods or numerical grading. Quantitative methods are the most extensive and use a probabilistic approach to quantify the risk based on both frequency and consequences.

See SFPE *Engineering Guide to Fire Risk Assessment* or AIChE *Guidelines for Hazard Evaluation Procedures* for more information.

N **A.3.3.44 Spark.** The term *spark* is commonly used to describe two distinct physical phenomena that are relevant to combustible dust hazards. A capacitive, or electrostatic, spark is a short-duration electrical discharge that occurs in a fixed location. A thermal spark, also referred to as a frictional spark or ember, is a small, hot particulate that can be transported from its origin. Thermal sparks can include frictional sparks, which are heated and ejected from frictional contact between two objects, and embers, which generate heat due to smoldering combustion.

N **A.3.3.44.1 Capacitive Spark.** A capacitive spark is one type of electrostatic discharge. Other types of electrostatic discharges include corona discharges, brush discharges, cone discharges, and propagating brush discharges. See NFPA 77 for more information. This definition does not include electrical arcs from energized electrical equipment.

N **A.3.3.44.2 Thermal Spark.** The term *thermal spark* is used to describe both frictional sparks such as those that occur from grinding operations and combustion embers that are transferred through particulate conveying systems.

A.4.1 Combustible particulate solids and dust hazard identification, assessment, and mitigation should address known hazards, including the following:

(1) Reactivity hazards (e.g., binary incompatibility or water reactivity)

(2) Smoldering fire in a layer or a pile
(3) Flaming fire of a layer or a pile
(4) Deflagration resulting in flash fire (dust cloud combustion)
(5) Deflagration resulting in dust explosion in equipment
(6) Deflagration resulting in dust explosion in rooms and buildings

A.4.2.1.1 Given the fast acting nature of flash fire, deflagration, and explosions, the stated Life Safety Objective recognizes the difficulty, if not the impossibility, of protecting occupants in the immediate proximity of the ignition. Thus, the stated objective is to protect occupants not in the immediate proximity of ignition. However, all available practices should be employed to ensure the safety of all persons both near and far from the ignition. An example of this might be the standard's prescriptive exception relative to the less than 8 ft^3 (0.2 m^3) air-material separator not requiring protection; however, the intent of the objective is to consider the effect of deflagration to occupants in the immediate area of the small air-material separator and mitigate this hazard if possible. Likewise, the standard has not defined "immediate proximity" in that this could mean within just feet of the hazard or within the same building or structure and leaves that judgment to the user. The intent of the objective is to employ all available and reasonable protection, techniques, and practices to protect all occupants understanding that it might not always be achievable.

A.4.2.2 Other stakeholders could also have mission continuity goals that will necessitate more stringent objectives as well as more specific and demanding performance criteria. The protection of property beyond maintaining structural integrity long enough to escape is actually a mission continuity objective.

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

A.4.2.3 Adjacent compartments share a common enclosure surface (wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion.

A.4.2.4 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.

Δ **A.5.2** Data derived from testing material sampled from the process being reviewed will be the most representative of the process. Testing is not required to determine whether the material has combustibility characteristics where reliable, in-house commodity-specific testing data or published data of well-characterized samples (i.e., particle size, moisture content, and test conditions) are available. Published data can be used for preliminary assessment of combustibility. Published data can also be used for protection or prevention design purposesif a thorough review indicates that the data are representative of owner/operator conditions.

The protection or prevention designs are based on explosivity properties, which can vary based on the specific characteristics of the material. Historical knowledge and experience of occurrence or nonoccurrence of process incidents such as flash fires, small fires, sparkling fires, pops, or booms, or evidence of vessel, tank, or container overpressure should not be used as a substitute for hazard analysis. Process incidents are indications of a material or process resulting in combustibility or explosion propensity. Process incidents can be used to guide or select samples for and supplement testing.

The following material properties should be addressed by a DHA 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:

   (a) Data presented in terms of the percent passing progressively smaller sieves.
   (b) Particles that have high aspect ratios can produce distorted, particle size results.
(2) *Particle Size Distribution.* The particle size distribution of a combustible particulate solid is an important parameter in assessing an explosion hazard. Particle size implies a specific surface area (SSA) and affects the numerical measure of other parameters such as MEC, MIE, dP/dt_{max}, P_{max}, and K_{St}. Spherical particles greater than 500 microns are generally not considered deflagratory. Most combustible particulate solids include a range of particle sizes in any given sample. The DHA should anticipate and account for particle attrition and separation as particulate is handled.
(3) *Particle Shape.* Due to particle shape and agglomeration, some particulates cannot be sieved effectively. Particulates with nonspheric or noncubic shapes do not pass through a sieve as easily as spheric or cubic particles. For this purpose, long fibers can behave just as explosively as spherical particulates of a similar diameter. This leads to underestimation of small particle populations and underassessment of the hazard. Particulates with an aspect ratio greater than 3:1 should be suspect. When particulates are poured into vessels, it is common for the fine particles to separate from the large, creating a deflagration hazard in the ullage space.
(4) *Particle Aging.* Some combustible particulate solid materials could undergo changes in their safety characteristics due to aging. Changes in morphology and chemical composition, for example, can occur from the time a sample is collected to the time it is tested. For materials that are known to age, care must be taken in packaging and shipment. The use of vacuum seals, or an inert gas such as nitrogen, could be required to ensure that the

tested sample has not changed appreciably due to aging. The lab should be notified in advance of shipment that the material is sensitive to change due to age so that they will know how to handle it and store it until it is tested.

(5) *Particle Attrition.* The material submitted for testing should be selected to address the effects of material attrition as it is moved through the process. As particulates move through a process they usually break down into smaller particles. Reduction in particle size leads to an increase in total surface area to mass ratio of the particulate and increases the hazard associated with the unoxidized particulate.

(6) *Particle Suspension.* Particle suspension maximizes the fuel–air interface. It occurs wherever the particulate moves relative to the air or the air moves relative to the particulate, such as in pneumatic conveying, pouring, fluidizing, mixing and blending, or particle size reduction.

(7) *Particle Agglomeration.* Some particulates tend to agglomerate into clumps. Agglomerating particulates can be more hazardous than the test data imply if the particulate was not thoroughly deagglomerated when testing was conducted. Agglomeration is usually affected by ambient humidity.

(8) *Triboelectric Attraction.* Particles with a chemistry that allows electrostatic charge accumulation will become charged during handling. Charged particles attract oppositely charged particles. Agglomeration causes particulate to exhibit lower explosion metrics during testing. Humidification decreases the triboelectric effect.

(9) *Hydrogen Bonding.* Hydrophilic particulates attract water molecules that are adsorbed onto the particle surface. Adsorbed water provides hydrogen bonding to adjacent particles, causing them to agglomerate. Agglomeration causes particulate to exhibit lower explosion metrics during testing. Desiccation reduces this agglomerated effect.

(10) *Entrainment Fraction.* The calculation for a dust dispersion from an accumulated layer should be corrected for the ease of entrainment of the dust. Fuel chemistry and agglomeration/adhesion forces should be considered. The dispersion is generally a function of humidity, temperature, and time. Particle shape and morphology and effective particle size should be considered.

(11) *Combustible Concentration.* When particles are suspended, a concentration gradient will develop where concentration varies continuously from high to low. There is a minimum concentration that must exist before a flame front will propagate. This concentration depends on particle size and chemical composition and is measured in oz/ft^3 (g/m^3). This concentration is called the minimum explosible concentration (MEC). A dust dispersion can come from a layer of accumulated fugitive dust. The concentration attained depends on bulk density of dust layer [measured in oz/ft^3 (g/m^3)], layer thickness, and the extent of the dust cloud. Combustible concentration is calculated as follows in Equation A.5.2:

N **[A.5.2]**

$$\text{Combustible concentration} = \text{Bulk density} \times \frac{\text{Layer thickness}}{\text{Dust cloud thickness}}$$

(12) *Competent Igniter.* Ignition occurs where sufficient energy per unit of time and volume is applied to a deflagratory particulate suspension. Energy per unit of mass is measured as temperature. When the temperature of the suspension is increased to the auto-ignition temperature, combustion begins. Ignitability is usually characterized by measuring the minimum ignition energy (MIE). The ignition source must provide sufficient energy per unit of time (power) to raise the temperature of the particulate to its autoignition temperature (AIT).

(13) *Dustiness/Dispersibility.* Ignition and sustained combustion occurs where a fuel and competent ignition source 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 combustible 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 heat flux from combustible metal flash fires is greater than organic materials. The four elements for a flash fire are the following:

  (a) A combustible dust sufficiently small enough to burn rapidly and propagate flame
  (b) A suspended cloud at a concentration greater than the minimum explosion concentration
  (c) The atmosphere to support combustion
  (d) An ignition source of adequate energy or temperature to ignite the dust cloud

A dust explosion requires the following five conditions *(see Figure A.5.2)*:

(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

Δ **A.5.2.2** Such an assessment is to determine whether the dust is a combustible dust and if further assessment is necessary. Data can be from samples within the facility that have been tested or data can be based on whether the material is known to be combustible or not. There are some published data of commonly known materials, and the use of these data is adequate to determine whether the dust is a combustible dust. For well-known commodities, published data are usually acceptable. A perusal of published data illuminates that there is often a significant spread in values. It is useful, therefore, to compare attributes (such as particle distribution and moisture content) in published data with the actual material being handled in the system whenever possible. Doing so would help to verify that the data are pertinent to the hazard under assessment.

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

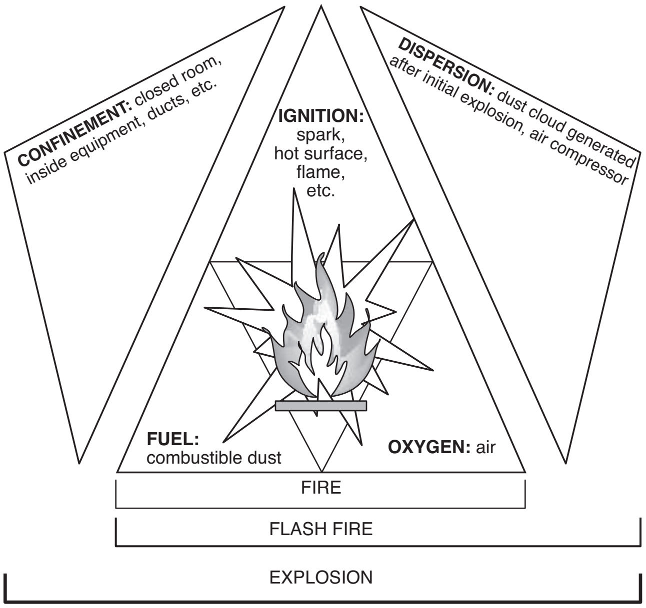

FIGURE A.5.2 Elements Required for Fires, Flash Fires, and Explosions.

it is representative of the conditions of the facility. Where that is not possible, the use of worst-case values should be selected.

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

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

A.5.3 Some materials have multiple potential physical hazards such as combustibility, explosibility, reactivity, and propensity to self-heat. This standard does not specifically address reactivity hazards of solid particulate materials. Users should consult SDS for specific information and guidance on safe handling, personal protective equipment, and storage and transportation of chemicals.

Δ **A.5.4.1.2** Results of the preliminary screening test can have one of the following four results:

(1) No reaction
(2) Glowing but no propagation along the powder train
(3) Propagation, but too slow to include the test material in Division 4.1
(4) Propagation sufficiently fast to qualify for inclusion in Division 4.1

If the results of the screening test show no reaction or glowing in the specific form, that material can be considered noncombustible and does not fall under the requirements of this document. If the results of the screening test show glowing but no propagation along the powder train, the material in the specific form should be considered a limited-combustible material. Hazard analysis should be conducted to determine the extent to which the requirements of this document are applicable.

It is recommended for general safety that the full requirements be met. If the results of the screening test show propagation of the powder train, the material in the specific form should be considered a limited-combustible material and full compliance with the requirements of this document be met. If the results of the screening test show propagation of the powder train sufficiently fast that the form is classified as a Division 4.1 material, hazard analysis should focus on additional protocols and compliance with other NFPA standards.

N **A.5.4.2** At this time, several organizations are in the early stages of developing testing methods to determine the flash-fire potential for combustible dusts. Currently, this document assesses the flash-fire potential existing concurrently with explosibility, as determined by existing test methods.

Δ **A.5.4.3.2** Testing a worst-case (finest) particle size distribution will provide a conservative determination of the combustibility of the material. *(See Table A.5.4.4.1.)*

A.5.4.3.3 Tests should typically be performed in accordance with the test standard recommendations. For example, most ASTM combustible dust test methods recommend testing the sample at less than 5 percent moisture by weight and particle size that is at least 95 percent sub-200 mesh (75 μm) screen by weight. This might require drying and grinding or sieving of samples. The thought behind this approach is to obtain near worst-case test data for accumulations that could be found within a facility [i.e., accumulations of dry fines, typically sub-200 mesh (75 μm), at some locations or changes in processes] and by doing so ensure conservatism in the hazard assessment and design of protection equipment.

This typically produces a built-in safety factor for the tests, as the testing laboratory does not know if the samples are a good representation of the dust from the facility. By performing the test in this manner, it typically assumes a worst-case scenario to account for dust accumulations not factored in by the facility.

On the other hand, testing material "as received" can result in a more realistic determination of the true nature of the hazard under assessment. Additionally, in some cases the as-received material could present a greater hazard than the dried fine fraction of the material. For instance, some samples might consist of a mixture of fine noncombustible material and coarse combustible material, where the fine fraction is a lower hazard than the as received material. Similarly, some water reactive materials could present a greater hazard with some moisture present than they would when dried. Determining the moisture content and particle size fraction of a dust sample is of considerable importance and should be done in consultation with experts or someone familiar with the process and material.

A.5.4.3.5 Tests conducted on iron and titanium nanoparticles using the standard 20 L test method described in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, have resulted in ignitions in the sample auxiliary chamber and the injection piping rather than the test vessel, where pressures are measured. *(See papers by Bouillard and Wu.)*

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

Dust Name	Percent Moisture	Median Particle Size (µm)	Percent <200 Mesh (%)	P_{max} (bar g)	(1) K_{St} (bar m/sec)	Minimum Explosive Concentration (g/m³)	Minimum Ignition Energy (mJ)
Alfalfa	2.1	36	83	6.7	94		
Angel Food Cake	4.1	41		7.5	132		
Apple		155	9	6.7	34	125	
Beet root		108	26	6.1	30	125	
Carrageenan	3.8		98	8.5	140		
Carrot	4.0	29	76	6.9	65		
Cereal dust (mixed)	4.4	121		6.7	74	265	
Cheesy pasta sauce mix (corn starch and spices)	7.9	<45	68	7.2	99		45
Chili sauce mix (corn starch and spices)	7.0	79	70	6.6	60		74
Cocoa bean dust	2.3	45	100	7.1	133		
Cocoa powder	3.9	194	14	8.0	162	65	100–180
Coconut shell dust	6.5		51	6.8	111		
Coffee dust – coarse particles	4.8	321	0.4	6.9	55		160*
Coffee dust – fine particles	4	40	100	7.7	158		
Corn (maize)	9.0	165		8.7	117	30	>10
Corn meal	8.2	403	0.6	6.2	47		
Cornstarch – coarse particles	2.2	217	0.1	7.9	186		30–60*
Cornstarch – fine particles		11	100	9.5	141	60	
Cotton		44	72	7.2	24	100	
Cottonseed		245	10	7.7	35	125	
Fudge brownie mix	4.8	221		5.8	43		
Garlic powder				8.6	164		
Gluten		150	33	7.7	110	125	
Grass dust		200		8.0	47	125	
Green coffee	5.0	45	81	7.8	116		
Hops (malted)		490	9	8.2	90		
Lemon peel dust	9.5	38	73	6.8	125		
Lemon pulp	2.8	180	17	6.7	74		
Linseed		300		6.0	17		
Locust bean gum	1.7		53	7.8	78		
Malt	10.5	72	54	7.5	170		
Milk powder	3.1	41	88	7.5	145		
Oat flour	4.3	180	0.2	6.8	64		
Oat grain dust		295		6.0	14	750	
Olive pellets				10.4	74	125	
Onion powder				9.0	157		
Parmesan sauce mix (corn starch and spices)	6.7	66	60	6.1	45		62
Parlsey (dehydrated)	5.4		26	7.5	110		
Peach		140	17	8.4	81	60	
Peanut meal and skins	3.8			6.4	45		
Peat		74	48	8.3	51	125	
Potato		82	30	6	20	250	
Potato flakes	8.0	249	7.0	6.2	33		
Potato flour		65	53	9.1	69	125	
Potato starch		32	100	9.4	89		>3200
Raw yucca seed dust	12.7	403	5	6.2	65		
Rice dust	2.5		4	7.7	118		40–120*
Rice flour	12.2	45	100	7.7	140	65	>500
Rice starch		18	90	10	190		

(continues)

N **Table A.5.2.2(a)** ***Continued***

Dust Name	Percent Moisture	Median Particle Size (μm)	Percent <200 Mesh (%)	P_{max} (bar g)	(1) K_{St} (bar m/sec)	Minimum Explosive Concentration (g/m³)	Minimum Ignition Energy (mJ)
Rye flour		29	76	8.9	79		
Semolina	13.6	57	100	7.0	109		
Snack mix spices	8.3	85		6.8	73		
Soybean dust	2.1		59	7.5	125		
Spice dust	10.0		2	6.9	65		
Spice powder	10.0			7.8	172		
Sugar, fine	1.3	45	100	7.6	117	135	38
Sugar, granulated	2	152	13	6.2	66		
Sugar, powdered	13	45	100	7.0	122		30*
Sunflower		420	10	7.9	44	125	
Tea	6.3	77	53	7.6	102	125	
Tobacco blend	1.0	120		8.0	124		
Tomato		200		1		100	
Walnut dust	6.0		31	8.4	174		
Wheat/rice cereal base	2.8	187		5.7	28	150	
Wheat/rice cereal base regrinds	6.4	217		6.4	29		
Wheat flour	12.9	57	60	8.3	87	60	
Wheat grain dust		80	48	9.3	112	60	
Wheat starch		20		9.8	132	60	25–60*
Xanthan gum	8.6	45	91	7.5	61		
Yellow cake mix	6.1	219		6.3	73		

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

Notes:

(1) Normalized to 1 m³ test vessel pressures, per ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds.*

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

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

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

Many nanoparticle materials are produced with special manufacturing equipment to obtain a narrow particle size distribution with a maximum particle size of 0.1 μm (100 nm). However, there are some applications in which nanoparticles can be produced inadvertently. For example, micromilling or air attrition milling are processes that can create nanoparticles. In those infrequent cases where there is a mix of particles smaller and larger than 0.5 μm, there do not seem to be test data to specify the precise percentage of nanoparticles needed to require special test methods or special interpretations of standard test data. Based on data for mixtures of inert and combustible dust particulates, an approximate percentage of at least 10 weight percent would be expected to produce results dominated by the more readily explosible material.

The applicability of other combustibility and explosibility test methods to nanoparticles has yet to be determined; therefore, no prescriptions are offered here. However, users of this standard should be aware of the possibility of special behavior of the nanoparticles.

A.5.4.4.1 Refer to Table A.5.4.4.1 for standard test methods for determining explosibility characteristics of dusts that are used for the DHA, performance-based design method risk assessments, and hazard management of combustible dusts.

ASTM E2021, *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 E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air,* is used to determine the 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 E2019 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.

Δ Table A.5.2.2(b) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Agricultural Dusts

Material	Mass Median Diameter (μm)	Minimum Flammable Concentration (g/m³)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
Cellulose	33	60	9.7	229	2
Cellulose pulp	42	30	9.9	62	1
Cork	42	30	9.6	202	2
Corn	28	60	9.4	75	1
Egg white	17	125	8.3	38	1
Milk, powdered	83	60	5.8	28	1
Milk, nonfat, dry	60	—	8.8	125	1
Soy flour	20	200	9.2	110	1
Starch, corn	7	—	10.3	202	2
Starch, rice	18	60	9.2	101	1
Starch, wheat	22	30	9.9	115	1
Sugar	30	200	8.5	138	1
Sugar, milk	27	60	8.3	82	1
Sugar, beet	29	60	8.2	59	1
Tapioca	22	125	9.4	62	1
Whey	41	125	9.8	140	1
Wood flour	29	—	10.5	205	2

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

Δ Table A.5.2.2(c) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Carbonaceous Dusts

Material	Mass Median Diameter (μm)	Minimum Flammable Concentration (g/m³)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
Charcoal, activated	28	60	7.7	14	1
Charcoal, wood	14	60	9.0	10	1
Coal, bituminous	24	60	9.2	129	1
Coke, petroleum	15	125	7.6	47	1
Lampblack	<10	60	8.4	121	1
Lignite	32	60	10.0	151	1
Peat, 22% H_2O	—	125	84.0	67	1
Soot, pine	<10	—	7.9	26	1

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

ASTM E1491, *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 E1491 (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 E1226, *Standard Test Method for Explosibility of Dust Clouds,* is used to determine the pressure and rate of pressure rise for suspended combustible dusts. The measurement of the explosibility parameters (P_{max} and K_{St}) requires the reproducible generation of a near homogeneous dust cloud inside a containment vessel of known volume. The explosibility parameters P_{max} (maximum pressure) and K_{St} (maximum rate of pressure rise of the worst-case concentration times the cube root of the test volume) are obtained from such measurements. The determination of a P_{max} and K_{St} for a material first establishes that it is an explosible dust. A bench scale test method in ASTM E1226 involves a vessel at least 20 L in volume in which a dust cloud is formed using the discharge of a small cylinder of compressed air. After a prescribed time delay, the highly turbulent dust cloud is ignited using a strong ignition source of known energy. Pressure is monitored versus time by appropriate transducers and expressed as pressure, P_{ex}, and pressure rate of rise, dP/dt_{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 μm ensuring a design that is conservative.

Δ Table A.5.2.2(d) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Chemical Dusts

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

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

Δ Table A.5.2.2(e) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen — Metal Dusts

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

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

The primary use of the test data P_{max} and K_{St} is for the design of explosion protection systems: venting, suppression, and 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 and requires knowledge of the process — volume, temperature, operating pressure, design strength, vent relief pressure — and of the fuel, P_{max} and K_{St}. Suppression is the active extinguishment of the combustion and again limits the explosion pressure to an acceptable level. Suppression designs require similar process and hazard data in order to determine the hardware requirements such as size, number, and location of containers, detection conditions, and the final or reduced explosion pressure. Isolation — the prevention of flame propagation through interconnections — requires the same process and hazard data to determine hardware needs and locations. The extent of testing should depend on what the scenario or evaluation such as explosion venting for a dust collector would require K_{St} and P_{max}.

Published data can be used for preliminary assessment only; they should not be used for design. While some materials are well-characterized, 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, NFPA 499, NFPA 68, and NFPA 484 have lists of combustible and explosible metals and dusts that are used for guidance or as informational references only and are not to be used for design purposes. Composition, particle size and distribution, and moisture content are the three factors 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 DHA should scrutinize and make informed judgments about historical and published data and its applicability to the process.

Δ Table A.5.2.2(f) 1 m³ Vessel Test Data from Forschungsbericht Staubexplosionen (except where noted) — Plastic Dusts

Material	Mass Median Diameter (μm)	Minimum Flammable Concentration (g/m³)	P_{max} (bar)	K_{St} (bar-m/s)	Dust Hazard Class
(poly) Acrylamide	10	250	5.9	12	1
(poly) Acrylonitrile	25	—	8.5	121	1
(poly) Ethylene (low-pressure process)	<10	30	8.0	156	1
Epoxy resin	26	30	7.9	129	1
Melamine resin	18	125	10.2	110	1
Melamine, molded (wood flour and mineral filled phenol-formaldehyde)	15	60	7.5	41	1
Melamine, molded (phenol-cellulose)	12	60	10.0	127	1
(poly) Methyl acrylate	21	30	9.4	269	2
(poly) Methyl acrylate, emulsion polymer	18	30	10.1	202	2
Phenolic resin	<10	15	9.3	129	1
	55		7.9	269	2
(poly) Propylene	25	30	8.4	101	1
Terpene-phenol resin	10	15	8.7	143	1
Urea-formaldehyde/ cellulose, molded	13	60	10.2	136	1
(poly) Vinyl acetate/ ethylene copolymer	32	30	8.6	119	1
(poly) Vinyl alcohol	26	60	8.9	128	1
(poly) Vinyl butyral	65	30	8.9	147	1
(poly) Vinyl chloride	107	200	7.6	46	1
(poly) Vinyl chloride/vinyl acetylene emulsion copolymer	35	60	8.2	95	1
(poly) Vinyl chloride/ethylene/vinyl acetylene suspension copolymer	60	60	8.3	98	1

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

Δ Table A.5.2.2(g) 20 L and 1 m³ Vessel Test Data, PVC and Copolymer Plastic Resins and Dusts

PVC Resin Sample	GP[a] Dispersion	VA[b] Copolymer	Baghouse Dust from GP Pipe (as received)	GP Pipe Resin[c]	Baghouse Dust from GP Pipe (as received)	GP Pipe Resin (as received)	High Molecular Weight Resin (as received)
	Type of polymerization process						
	Emulsion		Suspension				
Plant designator	A	B	C	C	D	D	E
Test lab	Chilworth	Chilworth	Chilworth	Fike	Chilworth	Chilworth (20 L), Fike (1 m³)	Fike
Minimum Ignition Energy (MIE), Joules	>10 J	>10 J	>500 mJ	>4653 mJ	>10 J	>10 J	>4468 mJ
Explosion severity, K_{St} (bar-m/s), 20 L test chamber	91	68	84	18	54	9	81
Dust explosion class in 20 L test chamber	ST 1	ST 1	ST 1	ST 1	ST 1	ST 1	ST 1
Explosion severity, K_{St} (bar-m/s), 1 m³ test chamber	Not tested	Not tested	Not tested	0	Not tested	0	0
Dust explosion class in 1 m³ test chamber	Not tested	Not tested	Not tested	ST 0	Not tested	ST 0	ST 0
Particle size, avg. (μm)	1 (est.)	N.A.	N.A.	162	N.A.	158	128
Dust fraction (<75 μm, %)	100	100	100	0.1	97	0	0.6

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

[a]GP: General Purpose

[b]VA: Vinyl Acetate

[c]Date for MIE and 20 L test were performed by Fike on sample screened to <150 μm and data for 1 m³ tests were performed by Fike on 'as received' sample.

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

Δ Table A.5.2.2(h) Explosibility Properties of Metals

Material	Median Diameter (μm)	K_{st} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m³)	UN Combustibility Category[2]	LOC[1] (v%)	Data Source
Aluminum	~7	—	8	—	—	90			Cashdollar & Zlochower4
Aluminum	22	—	—	—	—	—	—	5 (N)	BGIA3
Aluminum	<44	—	5.8	650	50	45		2 (C)	BuMines RI 6516
Aluminum flake	<44		6.1	650	20	45		<3 (C)	BuMines RI 6516
Aluminum	<10	515	11.2	560	—	60	—	—	BGIA3
Aluminum	580	Not Ignited	—	—	—	—	—	—	BGIA
Beryllium	4	Not Ignited	—	—	—	—	—	—	BuMines RI 6516
Boron	<44	—	—	470	60	<100	—	—	BuMines RI 6516
Boron	~3	—	6.0			≈110			Cashdollar & Zlochower
Bronze	18	31	4.1	390	—	750	BZ 4		Eckhoff
Chromium	6	—	3.3	660	5120	770		14 (C)	BuMines RI 6516
Chromium	3	—	3.9	580	140	230	—	—	BuMines RI 6517
Copper	~30	Not Ignited							Cashdollar & Zlochower
Hafnium	~8	—	4.2	—	—	~180	—	—	Cashdollar & Zlochower
Iron	12	50	5.2	580		500	—		Eckhoff
Iron	~45	—	2.1	—	—	~500	—	—	Cashdollar & Zlochower
Iron	< 44	—	2.8	430	80	170	—	13 (C)	BuMines RI 6516
Iron, carbonyl	< 10	111	6.1	310		125	BZ 3		Eckhoff
Manganese	< 44	—	—	460	305	125		—	BuMines RI 6516
Manganese (electrolytic)	16	157	6.3	330	—	—	—	—	Eckhoff
Manganese (electrolytic)	33	69	6.6	—	—	—	—	—	Eckhoff
Magnesium	28	508	17.5	—	—	—	—		Eckhoff
Magnesium	240	12	7	760		500	BZ 5		Eckhoff
Magnesium	<44	—	—	620	40	40		—	BuMines RI 6516
Magnesium	<44	—		600	240	30	—	<3 (C)	BuMines RI 6516
Magnesium	~16	—	7.5	—	—	55	—	—	Cashdollar & Zlochower
Molybdenum	<10	Not Ignited							Eckhoff
Nickel	~6	Not Ignited							Cashdollar & Zlochower
Niobium	80	238	6.3	560	3	70		6 (Ar)	Industry
Niobium	70	326	7.1	591	3	50		5 (Ar)	Industry
Silicon	<10	126	10.2	>850	54	125	BZ 3		Eckhoff
Silicon, from dust collector	16	100	9.4	800	—	60	—		Eckhoff
Silicon, from filter	<10	116	9.5	>850	250	60	BZ 1		Eckhoff
Tantalum	<44	—	—	630	120	<200		3 (Ar)	BuMines RI 6516
Tantalum	~10		≈3			≈400			Cashdollar & Zlochower
Tantalum	100	149	6.0	460	<3	160		2 (Ar)	Industry
Tantalum	80	97	3.7	540	<3	160		2(Ar)	Industry
Tantalum	50	108	5.5	520	<3	160		2(Ar)	Industry
Tantalum	65	129	5.8	460	<3	160		2(Ar)	Industry
Tantalum	21		5.6	430	<3	125		<2(Ar)	Industry
Tantalum	25			400	>1<3	30		<2(Ar)	Industry
Tin	~8	—	3.3	—	—	~450	—	—	Cashdollar & Zlochower
Titanium	36	Not Ignited				BZ 2			BGIA
Titanium	30	—	—	450	—	—	—		Eckhof
Titanium	~25		4.7	—	—	70	—		Cashdollar & Zlochower
Titanium	10	—	4.8	330	25	45		6 (N) 4 (Ar)	BuMines RI 6515
Tungsten	≤1	—	~2.3	—	—	~700	—	—	Cashdollar & Zlochower
Tungsten	~10	Not Ignited							Cashdollar & Zlochower
Zinc (from collector)	<10	125	6.7	570	—	250	BZ 3		Eckhoff
Zinc (from collector)	10	176	7.3	—	—	125	BZ 2		Eckhoff
Zinc (from Zn coating)	19	85	6	800	—	—	BZ 2		Eckhoff
Zinc (from Zn coating)	21	93	6.8	790	—	250	—		Eckhoff
Zirconium	<44	—	5.2	20	5	45	—	Ignites in N_2 & CO_2	BuMines RI 6516
Zirconium (Zircalloy-2)	50	—	3.0	420	30	—	—	—	BuMines RI 6516

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

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

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

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

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

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

Particle Size (d_{50}) (μm)	BET (m^2/g)	MEC (g/m^3)	P_{max} (psi)	dP/dt_{max} (psi/sec)	K_{St} (bar·m/sec)	Sample Concentration That Corresponds to P_{max} and dP/dt_{max} (g/m^3)	MIE (mJ)	LOC (%)	Most Easily Ignitible Concentration (g/m^3)
Nonspherical, Nodular, or Irregular Powders									
53	0.18	170	123	3,130	59	1,250			
42	0.19	70	133	5,720	107	1,250 (P_{max}), 1,000 (dP/dt_{max})			
32	0.34	60	142	7,950	149	1,250	10		
32	0.58	65	133	8,880	167	750 (P_{max}), 1,500 (dP/dt_{max})	11	Ignition @ 8.0% Nonignition @ 7.5%	1,000
30	0.10	60					10		
28	0.11	55	140	6,360	119	1,000 (P_{max}), 1,250 (dP/dt_{max})	11		
28	0.21	55	146	8,374	157	1,500	11		
9	0.90	65	165	15,370	288	750 (P_{max}), 1,000 (dP/dt_{max})	4		
7	0.74	90	153	17,702	332	1,000 (P_{max}), 500 (dP/dt_{max})	12		
6	0.15	80	176	15,580	292	750	3.5		
6	0.70	75	174	15,690	294	500 (P_{max}), 1,000 (dP/dt_{max})	3		
5	1.00	70					4		
4	0.78	75	167	15,480	291	1,000 (P_{max}), 750 (dP/dt_{max})	3.5		
Spherical Powders									
63	0.15	120	101	1,220	23	1,250 (P_{max}), 1,000 (dP/dt_{max})	N.I.	Ignition @ 8.0% Nonignition @ 7.5%	1,750
36	0.25	60	124	4,770	90	1,250	13		
30	0.10	60	140	5,940	111	1,000	13		
15	0.50	45	148	10,812	203	1,000	7		
15	0.30	55					8		
6	0.53	75	174	16,324	306	750	6		
5	1.30		167	14,310	269	750		Ignition @ 6.0% Nonignition @ 5.5%	750
5	1.00	70	155	14,730	276	1,250	6	Ignition @ 6.0% Nonignition @ 5.5%	1,250
3	2.50	95	165	15,900	298	1,250	4		
2	3.00	130							

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

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

Notes:

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

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

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

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

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

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

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

Note: K_{St} values vary for specific particle sizes.
*Burns in carbon dioxide, nitrogen, and halons.

N **A.5.4.4.4** If the material is a mixture of fine, noncombustible, and coarse combustible material, the fine fraction might not represent the most conservative sample. See 5.5.2.

A.5.5.1.3(4) Some materials are subject to change, such as oxidization or other chemical reaction, that could affect the test results. Precautions such as inerting or vacuum packing should be taken to preserve the test sample integrity. Other sample preservation considerations include the possibility of moisture reactions and polymerization reactions.

A.5.5.2 If the dust sample is a mixture of organic, inorganic, or combustible metals, the amount or concentration of each constituent should be determined by laboratory analysis. Common methods for an analysis of mixture composition include material separation, mass fraction analysis, energy dispersive x-ray spectroscopy, Fourier transform infrared spectroscopy, inductively coupled plasma spectroscopy, and x-ray fluorescence spectroscopy. Unique chemical reactivity issues could include water reactivity, reactivity with extinguishing agents, or other mixture constituents, pyrophoricity, chemical instability, oxidizer, and so forth. For example, for a mixture that contains some metal powder or dust, its potential for water reactivity should be considered based on the safety data sheet (SDS) or other public or company resources. If the potential for water reactivity exists, the entire mixture should be analyzed to determine whether it is water reactive. Generally the chemical category of the particulate can be determined based upon the combustible dust group as outlined in NFPA 499.

N **A.5.5.2.6** In some cases, the particle size or particle density differences of individual components of a mixture can cause segregation in different parts of a process or different areas of a vessel. In such cases, it can be difficult to predict the actual composition of the segregated materials. If the fine material is inert or less energetic than the coarse material, then testing the fine fraction per ASTM E1226, *Standard Test Method for Explosivity of Dust Clouds*, might not produce the highest explosivity values or lowest MIE values.

A.5.5.3 Special consideration should be given to samples from equipment in facilities such as dust collectors, impact equipment, silos and bins, processing equipment, ovens, furnaces, dryers, conveyors, bucket elevators, and grain elevators.

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

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

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

Some processes, such as grinding, require further evaluation. Grinding can result in a broad range of particle sizes. 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.

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A.5.5.4.1 The more information about a sample that is collected and tested, the more useful it is to manage, monitor stability, or track changes in the process and materials where a hazard is present or absent. Changes in the process or materials that require further testing will have a baseline for explaining any difference in physical hazard. Any dust sample collected from on top of a press should be identified as different from a sample collected from inside a vessel or container if the sample is susceptible to chemical changes (i.e., oxidation, hygroscopic) over time.

A.6.1.2 See A.4.2.4.

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

Chemical Name	CAS No.	NEC Group	Code	Layer or Cloud Ignition Temperature (°C)
Acetal, linear		G	NL	440
Acetoacet-p-phenetidide	122-82-7	G	NL	560
Acetoacetanilide	102-01-2	G	M	440
Acetylamino-t-nitrothiazole		G		450
Acrylamide polymer		G		240
Acrylonitrile polymer		G		460
Acrylonitrile-vinyl chloride-vinylidenechloride copolymer (70-20-10)		G		210
Acrylonitrile-vinyl pyridine copolymer		G		240
Adipic acid	124-04-9	G	M	550
Alfalfa meal		G		200
Alkyl ketone dimer sizing compound		G		160
Allyl alcohol derivative (CR-39)		G	NL	500
Almond shell		G		200
Aluminum, A422 flake	7429-90-5	E		320
Aluminum, atomized collector fines		E	CL	550
Aluminum—cobalt alloy (60-40)		E		570
Aluminum—copper alloy (50-50)		E		830
Aluminum—lithium alloy (15% Li)		E		400
Aluminum—magnesium alloy (dowmetal)		E	CL	430
Aluminum—nickel alloy (58-42)		E		540
Aluminum—silicon alloy (12% Si)		E	NL	670
Amino-5-nitrothiazole	121-66-4	G		460
Anthranilic acid	118-92-3	G	M	580
Apricot pit		G		230
Aryl-nitrosomethylamide		G	NL	490
Asphalt	8052-42-4	F		510
Aspirin [acetol (2)]	50-78-2	G	M	660
Azelaic acid	109-31-9	G	M	610
Azo-bis-butyronitrile	78-67-1	G		350
Benzethonium chloride		G	CL	380
Benzoic acid	65-85-0	G	M	620
Benzotriazole	95-14-7	G	M	440
Beta-naphthalene-axo- dimethylaniline		G		175
Bis(2-hydroxy- 5-chlorophenyl) methane	97-23-4	G	NL	570
Bisphenol-A	80-05-7	G	M	570
Boron, commercial amorphous (85% B)	7440-42-8	E		400
Calcium silicide		E		540
Carbon black (more than 8% total entrapped volatiles)		F		
Carboxymethyl cellulose	9000-11-7	G		290
Carboxypolymethylene		G	NL	520
Cashew oil, phenolic, hard		G		180
Cellulose		G		260
Cellulose acetate		G		340
Cellulose acetate butyrate		G	NL	370
Cellulose triacetate		G	NL	430
Charcoal (activated)	64365-11-3	F		180
Charcoal (more than 8% total entrapped volatiles)		F		
Cherry pit		G		220
Chlorinated phenol		G	NL	570
Chlorinated polyether alcohol		G		460
Chloroacetoacetanilide	101-92-8	G	M	640
Chromium (97%) electrolytic, milled	7440-47-3	E		400
Cinnamon		G		230
Citrus peel		G		270
Coal, Kentucky bituminous		F		180
Coal, Pittsburgh experimental		F		170
Coal, Wyoming		F		180
Cocoa bean shell		G		370

(continues)

Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. *N* = New material.

Δ Table A.5.2.2(k) ***Continued***

Chemical Name	CAS No.	NEC Group	Code	Layer or Cloud Ignition Temperature (°C)
Cocoa, natural, 19% fat		G		240
Coconut shell		G		220
Coke (more than 8% total entrapped volatiles)		F		
Cork		G		210
Corn		G		250
Corn dextrine		G		370
Corncob grit		G		240
Cornstarch, commercial		G		330
Cornstarch, modified		G		200
Cottonseed meal		G		200
Coumarone-indene, hard		G	NL	520
Crag No. 974	533-74-4	G	CL	310
Cube root, South America	83-79-4	G		230
Di-alphacumyl peroxide, 40-60 on CA	80-43-3	G		180
Diallyl phthalate	131-17-9	G	M	480
Dicyclopentadiene dioxide		G	NL	420
Dieldrin (20%)	60-57-1	G	NL	550
Dihydroacetic acid		G	NL	430
Dimethyl isophthalate	1459-93-4	G	M	580
Dimethyl terephthalate	120-61-6	G	M	570
Dinitro-o-toluamide	148-01-6	G	NL	500
Dinitrobenzoic acid		G	NL	460
Diphenyl	92-52-4	G	M	630
Ditertiary-butyl-paracresol	128-37-0	G	NL	420
Dithane m-45	8018-01-7	G		180
Epoxy		G	NL	540
Epoxy-bisphenol A		G	NL	510
Ethyl cellulose		G	CL	320
Ethyl hydroxyethyl cellulose		G	NL	390
Ethylene oxide polymer		G	NL	350
Ethylene-maleic anhydride copolymer		G	NL	540
Ferbam™	14484-64-1	G		150
Ferromanganese, medium carbon	12604-53-4	E		290
Ferrosilicon (88% Si, 9% Fe)	8049-17-0	E		800
Ferrotitanium (19% Ti, 74.1% Fe, 0.06% C)		E	CL	380
Flax shive		G		230
Fumaric acid	110-17-8	G	M	520
Garlic, dehydrated		G	NL	360
Gilsonite	12002-43-6	F		500
Green base harmon dye		G		175
Guar seed		G	NL	500
Gulasonic acid, diacetone		G	NL	420
Gum, arabic		G		260
Gum, karaya		G		240
Gum, manila		G	CL	360
Gum, tragacanth	9000-65-1	G		260
Hemp hurd		G		220
Hexamethylene tetramine	100-97-0	G	S	410
Hydroxyethyl cellulose		G	NL	410
Iron, 98% H2 reduced		E		290
Iron, 99% carbonyl	13463-40-6	E		310
Isotoic anhydride		G	NL	700
L-sorbose		G	M	370
Lignin, hydrolized, wood-type, fine		G	NL	450
Lignite, California		F		180
Lycopodium		G		190
Malt barley		G		250
Manganese	7439-96-5	E		240
Magnesium, grade B, milled		E		430

(continues)

Δ Table A.5.2.2(k) *Continued*

Chemical Name	CAS No.	NEC Group	Code	Layer or Cloud Ignition Temperature (°C)
Manganese vancide		G		120
Mannitol	69-65-8	G	M	460
Methacrylic acid polymer		G		290
Methionine (l-methionine)	63-68-3	G		360
Methyl cellulose		G		340
Methyl methacrylate polymer	9011-14-7	G	NL	440
Methyl methacrylate-ethyl acrylate		G	NL	440
Methyl methacrylate-styrene- butadiene		G	NL	480
Milk, skimmed		G		200
N,N-dimethylthio- formamide		G		230
Nitropyridone	100703-82-0	G	M	430
Nitrosamine		G	NL	270
Nylon polymer	63428-84-2	G		430
Para-oxy-benzaldehyde	123-08-0	G	CL	380
Paraphenylene diamine	106-50-3	G	M	620
Paratertiary butyl benzoic acid	98-73-7	G	M	560
Pea flour		G		260
Peach pit shell		G		210
Peanut hull		G		210
Peat, sphagnum	94114-14-4	G		240
Pecan nut shell	8002-03-7	G		210
Pectin	5328-37-0	G		200
Pentaerythritol	115-77-5	G	M	400
Petrin acrylate monomer	7659-34-9	G	NL	220
Petroleum coke (more than 8% total entrapped volatiles)		F		
Petroleum resin	64742-16-1	G		500
Phenol formaldehyde	9003-35-4	G	NL	580
Phenol formaldehyde, polyalkylene-p	9003-35-4	G		290
Phenol furfural	26338-61-4	G		310
Phenylbetanaphthylamine	135-88-6	G	NL	680
Phthalic anydride	85-44-9	G	M	650
Phthalimide	85-41-6	G	M	630
Pitch, coal tar	65996-93-2	F	NL	710
Pitch, petroleum	68187-58-6	F	NL	630
Polycarbonate		G	NL	710
Polyethylene, high pressure process	9002-88-4	G		380
Polyethylene, low pressure process	9002-88-4	G	NL	420
Polyethylene terephthalate	25038-59-9	G	NL	500
Polyethylene wax	68441-04-8	G	NL	400
Polypropylene (no antioxidant)	9003-07-0	G	NL	420
Polystyrene latex	9003-53-6	G		500
Polystyrene molding compound	9003-53-6	G	NL	560
Polyurethane foam, fire retardant	9009-54-5	G		390
Polyurethane foam, no fire retardant	9009-54-5	G		440
Polyvinyl acetate	9003-20-7	G	NL	550
Polyvinyl acetate/alcohol	9002-89-5	G		440
Polyvinyl butyral	63148-65-2	G		390
Polyvinyl chloride-dioctyl phthalate		G	NL	320
Potato starch, dextrinated	9005-25-8	G	NL	440
Pyrethrum	8003-34-7	G		210
Rayon (viscose) flock	61788-77-0	G		250
Red dye intermediate		G		175
Rice		G		220
Rice bran		G	NL	490
Rice hull		G		220
Rosin, DK	8050-09-7	G	NL	390
Rubber, crude, hard	9006-04-6	G	NL	350
Rubber, synthetic, hard (33% S)	64706-29-2	G	NL	320

(continues)

Δ Table A.5.2.2(k) ***Continued***

Chemical Name	CAS No.	NEC Group	Code	Layer or Cloud Ignition Temperature (°C)
Safflower meal		G		210
Salicylanilide	87-17-2	G	M	610
Sevin	63-25-2	G		140
Shale, oil	68308-34-9	F		
Shellac	9000-59-3	G	NL	400
Sodium resinate	61790-51-0	G		220
Sorbic acid (copper sorbate or potash)	110-44-1	G		460
Soy flour	68513-95-1	G		190
Soy protein	9010-10-0	G		260
Stearic acid, aluminum salt	637-12-7	G		300
Stearic acid, zinc salt	557-05-1	G	M	510
Styrene modified polyester-glass fiber	100-42-5	G		360
Styrene-acrylonitrile (70-30)	9003-54-7	G	NL	500
Styrene-butadiene latex (>75% styrene)	903-55-8	G	NL	440
Styrene-maleic anhydride copolymer	9011-13-6	G	CL	470
Sucrose	57-50-1	G	CL	350
Sugar, powdered	57-50-1	G	CL	370
Sulfur	7704-34-9	G		220
Tantalum	7440-25-7	E		300
Terephthalic acid	100-21-0	G	NL	680
Thorium (contains 1.2% O)	7440-29-1	E	CL	270
Tin, 96%, atomized (2% Pb)	7440-31-5	E		430
Titanium, 99% Ti	7440-32-6	E	CL	330
Titanium hydride (95% Ti, 3.8% H)	7704-98-5	E	CL	480
Trithiobisdimethylthio- formamide		G		230
Tung, kernels, oil-free	8001-20-5	G		240
Urea formaldehyde molding compound	9011-05-6	G	NL	460
Urea formaldehyde-phenol formaldehyde	25104-55-6	G		240
Vanadium, 86.4%	7440-62-2	E		490
Vinyl chloride-acrylonitrile copolymer	9003-00-3	G		470
Vinyl toluene-acrylonitrile butadiene	76404-69-8	G	NL	530
Violet 200 dye		G		175
Vitamin B1, mononitrate	59-43-8	G	NL	360
Vitamin C	50-81-7	G		280
Walnut shell, black		G		220
Wheat		G		220
Wheat flour	130498-22-5	G		360
Wheat gluten, gum	100684-25-1	G	NL	520
Wheat starch		G	NL	380
Wheat straw		G		220
Wood flour		G		260
Woodbark, ground		G		250
Yeast, torula	68602-94-8	G		260
Zirconium hydride	7704-99-6	E		270
Zirconium (contains 0.3% O)	7440-67-7	E	CL	330

Notes:
1. Normally, the minimum ignition temperature of a layer of a specific dust is lower than the minimum ignition temperature of a cloud of that dust. Since this is not universally true, the lower of the two minimum ignition temperatures is listed. If no symbol appears in the "Code" column, then the layer ignition temperature is shown. "CL" means the cloud ignition temperature is shown. "NL" means that no layer ignition temperature is available, and the cloud ignition temperature is shown. "M" signifies that the dust layer melts before it ignites; the cloud ignition temperature is shown. "S" signifies that the dust layer sublimes before it ignites; the cloud ignition temperature is shown.
2. Certain metal dusts might have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium and thorium dusts can ignite spontaneously in air, especially at elevated temperatures.
3. Due to the impurities found in coal, its ignition temperatures vary regionally, and ignition temperatures are not available for all regions in which coal is mined.
[**499:** Table 5.2.2]

Δ **Table A.5.4.4.1 Standard Test Methods to Determine Explosibility Properties**

Method	Property
ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*	Minimum ignition energy (MIE) of dust cloud in air
ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds*	Minimum ignition temperature (T_c) of dust clouds
ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*	Maximum explosion pressure (P_{max}), rate and maximum rate of pressure rise (dP/dt), and explosion severity (K_{St})
ASTM E1515, *Test Method for Minimum Explosible Concentration of Combustible Dusts*	Minimum explosible concentration (MEC)
ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*	Minimum ignition temperature (T_c) of dust layers
ASTM E2931, *Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*	Limiting oxygen concentration (LOC)

Δ **A.6.1.3.1** The *SFPE Engineering Guide to Performance-Based Fire Protection* describes the documentation that will be provided for a performance-based design.

Proper documentation of a performance-based design is critical to design acceptance and construction. Proper documentation will ensure that all parties involved understand the factors necessary for the implementation, maintenance, and continuity of the fire protection design. If attention to detail is maintained in the documentation, there should be little dispute during approval, construction, startup, and use.

Poor documentation could result in rejection of an otherwise good design, poor implementation of the design, inadequate system maintenance and reliability, and an incomplete record for future changes or for testing the design forensically.

Δ **A.6.1.4** Chapter 5 of NFPA *101* provides a more complete description of the performance-based design process and requirements. In addition, the SFPE *Engineering Guide to Performance-Based Fire Protection* outlines a process for developing, evaluating, and documenting performance-based designs.

A.6.1.4.1 The sources, methodologies, and data used in performance-based designs should be based on technical references that are widely accepted and used by the appropriate professions and professional groups. This acceptance is often based on documents that are developed, reviewed, and validated under one of the following processes:

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

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

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

In many cases, a method will be built from and include numerous component analyses. Such component analyses should be evaluated using the same acceptability factors that are applied to the overall method, as outlined in items A.6.1.4.1(1) through A.6.1.4.1(5).

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

The technical references and methodologies to be used in a performance-based design should be closely evaluated by the design team, the AHJ, and possibly a third-party reviewer. The strength of the technical justification should be judged using criteria in items A.6.1.4.1(1) through A.6.1.4.1(5). This justification can be strengthened by the presence of data obtained from fire or explosion testing.

A.6.1.5 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 8.12.

A.6.1.7 As used in this section, maintenance includes the preventive maintenance required for the design features that are part of the performance-based design and the requirement to maintain the design itself.

A.6.1.7.1 Design features, including protection methods and means and administrative controls, should be included in preventive maintenance programs to ensure their continued operability.

A.6.1.7.2 This is not intended to prohibit future variations in the design features but only that when modified these features are again subject to AHJ review.

A.6.3.1.1 When evaluating tenable conditions, the toxicity of hazardous materials released as a result of a fire or explosion should be considered.

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

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

A.6.4.2.5 For instance, some combustible metals can generate hydrogen when in contact with water. See NFPA 484 for additional information.

Δ **A.6.5.1** The SFPE *Engineering Guide to Performance-Based Fire Protection* outlines a process for evaluating whether trial designs meet the performance criteria.

Δ **A.7.1** This chapter provides the minimum requirements for performing a hazard assessment to identify and analyze the hazards presented by the presence of combustible particulate solids for the purpose of identifying relevant management strategies necessary to provide a reasonable degree of protection to life and property.

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

A.7.1.1.1 A DHA is a careful review of the fire and explosion hazards to determine the consequences of what could go wrong and to determine what safeguards could be implemented to prevent or mitigate those consequences. DHA should be completed as soon as possible. For existing facilities, those processes with the greatest perceived risk should be evaluated first.

A.7.1.1.2 The deadline for completing initial DHAs is 5 years after the effective date of the first edition of this standard.

This edition extends the first edition's period of 3 years for completion of all DHAs to 5 years. It is not the intent of this requirement to permit a delay in the completion of all DHA until the fifth year.

A.7.2.1 NFPA standards rely on the determination of "where an explosion hazard or deflagration hazard exists." There are other physical and health hazards to consider such as toxicity, reactivity with water, and so forth that can be considered when conducting a DHA. The DHA 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.

Δ **A.7.2.2** The qualified person who is leading or performing the DHA should be familiar with conducting a DHA. The qualified person should also be familiar with the hazards of combustible dusts. Typically, a team performs a DHA. For some processes this team might be a little as two persons, or for larger and more complex processes, the team might require 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 DHA could include facility operators, engineers, owners, equipment manufacturers, or consultants.

A.7.3.1(2)(b) The hazard management document for all the areas of the process or facility compartment determined to be combustible dust hazards 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 combustible dust hazards can be developed by using the methods permitted in this standard or other industry- or commodity-specific NFPA standards. Subsection 7.3.1 outlines the minimum steps of a dust hazards analysis.

A.7.3.3.1 This includes the process systems and ancillary equipment such as dust collection systems. Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate.

Δ **A.7.3.3.3** 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.)*

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

A.7.3.4.2.1 Refer to 6.1.1.3 and 6.1.1.8 of NFPA 654 and 6.4.2.2 of NFPA 664 for examples of methods to determine acceptable threshold accumulation level.

A.8.2 See ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems.*

A.8.3.1 The operating procedures should address both the normal operating conditions and 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 combustible dust hazards.

Operating procedures and practices should be reviewed on a periodic basis, typically annually, to ensure they are current and accurate.

A.8.3.2 Safe work practices include, but are not limited to, hot work, confined space entry, and lockout/tagout, and the use of personal protective equipment. *(See NFPA 51B.)* Consideration for extending the duration of the fire watch could be warranted based on characteristics of the material, equipment configuration, and conditions. For example, the PRB Coal Users' Group practice for hot work suggests fire watches could be warranted for 2 to 12 hours following the completion of hot work due to the exothermic chemical reaction of sub-bituminous coals. In addition to the hazards of combustible dust, safe work practices should address the hazards of mitigation systems such as inerting and suppression.

A.8.4.2 Model Programs Annex. (Reserved)

A.8.4.2.1.1 Items that should be included in the housekeeping procedure include the following:

(1) A risk assessment that considers the specific characteristics of the dust being cleaned (particle size, moisture content, MEC, MIE) and other safety risks introduced by the cleaning methods used
(2) Personal safety procedures, including fall protection when working at heights
(3) Personal protective equipment (PPE), including flame-resistant garments in accordance with the hazard analysis required by NFPA 2113
(4) Cleaning sequence
(5) Cleaning methods to be used
(6) Equipment, including lifts, vacuum systems, attachments, and so forth
(7) Cleaning frequency

Δ **A.8.4.2.1.2** For information on selection of housekeeping methods, refer to 2.2.4 of FM Data Sheet 7-76, "Prevention and Mitigation of Combustible Dust Explosions and Fires." Other factors can be considered in the selection of a housekeeping method, such as the effectiveness or compatibility of certain methods with the material. Cleaning should be comprehensive and should remove dust from the facility versus relocating it to other surfaces in the area. For the purposes of this standard, the concern is about dust that either propagates flame or that can be dispersed by credible disturbances. For accumulations that are not easy to disperse, the fire hazard should be considered *(see Section 8.10)*.

The accumulation of a dust layer on a surface that is subject to heating (e.g., the surface of a bearing, an electrical motor, or a heater) could insulate the surface, increasing the surface temperature above the equipment "T" rating, to the point where the dust could self-ignite and smolder.

Housekeeping of a dust layer that has self-ignited and started smoldering could result in full-ignition as the dust disperses during the housekeeping process. The burning dust could damage the housekeeping equipment, ignite a larger dust cloud or a flammable gas release in the area, or initiate smoldering in other dust layers. Before performing housekeeping of a dust layer on a potentially hot surface, the dust should be tested to confirm whether self-ignition and smoldering has initiated. Note that housekeeping of dust layers settling after a dust flash-fire should also consider the dust to be smoldering.

N **A.8.4.2.2.1** Portable vacuum cleaners are self-contained units that typically utilize either an electrically or compressed air powered (with venturi) vacuum source (AMD) and an air-material separator (AMS) that is either wet (i.e., liquid) or dry (i.e., filter media). A single hose connection is normally provided, but larger semiportable units (either on trucks or moved by forklifts) can allow use of more than one simultaneous operator. Typically, when dry filter media is used there is no automatic filter cleaning method; however, with the larger semiportable units automatic filter cleaning is usually provided due to the higher air flows and material/dust loading.

N **A.8.4.2.2.1.2** Using a portable vacuum cleaner with metal dusts and particles can have risks that are not adequately covered in NFPA 652. However, NFPA 484 has specific sections for use of wet and dry portable vacuum cleaning equipment and on their use with the more exotic metals and alloys such as titanium, aluminum, and so forth.

N **A.8.4.2.2.1.3** Use of portable vacuum cleaning equipment for housekeeping of combustible dusts is subject to the same dust hazards analysis (DHA) as would be a centralized vacuum cleaning system. The combustible dust characteristics, hazards, and risks should be analyzed to determine the best type of portable unit to use and the restrictions on their use. This should also consider the classification of the area of use, personnel protective equipment, and so forth.

N **A.8.4.2.2.1.6** Verification of the path to ground can be visual.

A.8.4.2.2.1.7 If a large quantity of material is spilled in an unclassified area, the bulk material should be collected by sweeping or shoveling or with a portable vacuum cleaner listed as suitable for Class II locations. Vacuum cleaners meeting the requirements in 8.4.2.2.1 can be used to clean up residual material after the bulk of the spill has been collected.

A.8.4.2.2.1.7(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.8.4.2.2.2 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.8.4.2.3 With manual cleaning, such as using a scoop and brush, generating a dust cloud should be avoided. Where appropriate for the specific commodity, the use of natural bristle brushes should be considered to reduce the risk of static sparking.

A.8.4.2.4 Use of high-pressure water can generate dust clouds, and care should be taken when using this method. Use of water wash-down for some metal dusts can result in hydrogen generation. Refer to NFPA 484 for restrictions on the use of water wash-down.

A.8.4.2.4.3 Examples of additional precautions to be taken can include, but are not limited to, the following:

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

A.8.4.2.6.1 Compressed air blowdown used for cleaning purposes has been demonstrated to present significant hazards and should be employed when other cleaning methods present higher risk. Compressed air blowdown does not remove accumulated dust, it simply moves the dust to another area, which will then have to be cleaned. It is preferable to use engineering design controls to eliminate areas that can be inaccessible or difficult to clean by other methods.

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

A.8.4.6.1 Surfaces on which dust can accumulate can include walls, floors, and horizontal surfaces, such as equipment, ducts, pipes, hoods, ledges, beams, and above suspended ceilings and other concealed surfaces such as the interior of electrical enclosures.

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

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

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

Table A.8.4.6.3 Unscheduled Housekeeping

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

A.8.4.7.1 Typically, the housekeeping effectiveness is verified on an annual basis or after a significant change in the operation. If transient releases are becoming more frequent, the housekeeping effectiveness and equipment integrity should be verified.

Δ **A.8.5.1** 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.8.5.2 The hot work area specified in NFPA 51B is 11 m (35 ft).

A.8.6.1.1 A specific evaluation of the work environment to determine the requirement for the wearing of flame-resistant garments should be based on the potential hazards that workers are exposed to as part of their work duties.

A.8.6.1.3 It is important to distinguish between the different PPE requirements in NFPA 2112 and *NFPA 70E* for different exposure hazards. The PPE requirements in NFPA 2112 are not the same requirements in *NFPA 70E* and might not be sufficient protection for electric arc.

A.8.6.1.4 Portions of this list are taken from Section 4.3 of NFPA 2113.

A.8.6.1.6 At a minimum, the policy should address who is responsible for laundering, inspecting, repairing, and retiring garments. See also Section 6.1 from NFPA 2113. If flame-resistant clothing becomes contaminated with combustible particulate solids, the protective performance of the garments could be compromised. Wearers should maintain an awareness of and take precautions against the accumulation of combustible particulate solids on their protective clothing.

A.8.6.2.1 This section does not include an incidental amount of elastic used in nonmelting fabric, underwear, or socks.

A.8.6.2.2 See also Section 5.1 from NFPA 2113.

Δ **A.8.7.1** 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 and NFPA 69, respectively.

A.8.7.2(5) Process interlocks should be calibrated and tested in the manner in which they are intended to operate, with written test records maintained for review by management. Testing frequency should be determined in accordance with the AIChE *Guidelines for Safe Automation of Chemical Processes.* [**654:**A.12.1.2(5)]

A.8.7.4 Corrective actions should be expedited on high-risk hazards (those that could result in a fatality or serious injury). Where in-kind repairs cannot be promptly implemented, consideration should be given to providing alternate means of protection.

A.8.7.5 See Section 8.13 for information regarding document retention.

A.8.8.1 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.8.8.2 All plant personnel, including management; supervisors; and operating, housekeeping, and maintenance personnel should receive general awareness training for combustible dust hazards, commensurate with their job responsibilities, including training on locations where hazards can exist on site, appropriate measures to minimize hazards, and response to emergencies.

Δ **A.8.8.2.1** 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.8.8.2.3 The extent of this training should be based on the level of interaction the person is expected to have with the system. For example, operators need to be aware of the hazards presented by explosion suppression systems but might not need to know how to operate the suppression system (e.g., interfacing with the system control panel or locking out devices). Maintenance personnel, on the other hand, might need to know how and when to lock out the devices and how to return the system to its operational state.

A.8.9.2 Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps, professional licenses, and so forth.

A.8.9.3 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.8.9.3.3 In addition to the combustible dust fire and explosion hazards, contractors should also be made aware of other potential process and occupational hazards. There can be combustible materials other than combustible dusts in the equipment or immediate vicinity where contractors might be working. Combustion of dusts can generate toxic products, and some combustible dusts are acutely toxic.

A.8.10.1 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 the 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. *(See OSHA's publication, Firefighting Precautions at Facilities with Combustible Dust, for additional information.)*

A.8.11 To thoroughly assess the risks, analyze the incident, and take any corrective steps necessary, investigations should be conducted promptly based on the nature of the incident and in coordination with the AHJ (as applicable).

The investigation should include root cause analysis and should include a review of existing control measures and underlying systemic factors. Appropriate corrective action should be taken to prevent recurrence and to assess and monitor the effectiveness of actions taken.

Such investigations should be carried out by trained persons (internal or external) and include participation of workers. All investigations should conclude with a report on the action taken to prevent recurrence.

Investigation reports should be reviewed with all affected personnel and their representatives (including contract employees where applicable) whose job tasks are relevant to the incident findings, and with the health and safety committee, to make any appropriate recommendations. Any recommendations from the safety and health committee should be communicated to the appropriate persons for corrective action, included in the management review, and considered for continual improvement activities.

A system should be established to promptly address and resolve the incident report findings and recommendations.

Corrective actions resulting from investigations should be implemented in all areas where there is a risk of similar incidents and subsequently checked to avoid repetition of injuries and incidents that gave rise to the investigation.

Reports produced by external investigation agencies should be acted upon in the same manner as internal investigations.

Incident investigation reports should be made available to affected employees and their representatives at no cost.

A.8.11.1 Events where there are injuries, equipment damage, or significant business interruption are subject to investigation.

In addition to investigation of fires and explosions, it is also a good practice to investigate near misses (events that could have resulted in fires or explosions under different circumstances) and all activations of active fire and explosion mitigation systems. It is important to educate facility personnel on the concept of what a near miss is and to clearly communicate their responsibility for reporting both incidents and near misses.

Near-miss events often indicate an underlying problem that should be corrected. See NFPA 654 for additional information. Barriers to reporting should be removed, as described in ANSI/AIHA Z10, *Occupational Health and Safety Management Systems*. Investigations should include workers and their representatives, as appropriate.

A.8.11.4 The term *affected personnel* is intended to include members of employee organizations such as safety committees and employee representatives of various types.

A.8.12.1 It is essential to have thorough written documentation, as the slightest changes to procedures, processes, resources, staffing, and equipment, including equipment from suppliers, can have a dramatic impact on the overall hazard analysis. Change includes something as benign as process materials sourcing from a different manufacturer, the same raw material manufacturer using new methods to produce the product, or changes in formulation. These changes from a supplier's end can impact the characteristics of the processes and materials. Individuals involved should include those involved in the process such as maintenance, engineering, and purchasing personnel, and all others as deemed necessary. Staffing and job tasks are not intended for shift changes, but for overall staff and their representative tasks. For reference, see the documentation form in ANSI/AIHA Z10, *Occupational Health and Safety Management Systems.*

The following changes in material or process should warrant a management of change review per Section 8.12, and new samples should be collected and analyzed:

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

A.8.12.2(1) The proposed change and why it is needed should be described. It should include sufficient technical information to facilitate review by the approvers, address adverse effects that could occur, and describe how such effects would be mitigated by the proposed change.

A.8.12.2(2) Some fire and explosion protection systems introduce additional hazards into the process environment. These hazards can include, but are not limited to, energy in suppression canisters, asphyxiation hazards from inert gases, and mechanical laceration/amputation hazards from explosion isolation systems. While these are not fire or explosion hazards, they should be addressed as part of the management of change review per this document so that appropriate controls can be applied.

A.8.12.3 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 8.12.2, 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.8.13 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.8.13.1(3) Incident investigation reports should be maintained for review during cyclical hazards evaluation reviews at least until the changes are incorporated in the dust hazards analysis and for compliance with other regulatory requirements.

A.8.13.1(5) Process and technology information includes process performance parameters, properties of the materials being handled, and 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 operation.

A.8.13.1(6) Management of change documents should be retained until the changes are incorporated into the next dust hazards analysis.

A.8.13.1(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.8.15 Effective employee participation is an essential element of the Occupational Health and Safety Management System (OHSMS) to achieve continuous improvement in risk reduction, as described in ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems*. The OHSMS ensures that employees and their authorized representatives are involved, informed, and trained on all aspects of health associated with their work, including emergency arrangements. Employee participation includes items such as, but not limited to, the following:

(1) Involving employees and their authorized representatives, where they exist, in establishing, maintaining, and evaluating the OSHMS
(2) An occupational health and safety committee
(3) Access to safety and health information
(4) Risk assessment, implementation, and review of risk control measures
(5) Incident and near-miss investigations
(6) Inspections and audits
(7) Reporting unsafe conditions, tools, equipment, and practices
(8) Mentoring of new employees, apprentices, and for on-site orientation
(9) Identifying hazards with strong emphasis on high-risk jobs and the application of the hierarchy of controls
(10) In accordance with established and maintained procedures, appropriate arrangements to ensure that concerns, ideas, and input that employees and their representatives share are received, considered, and responded to
(11) Employees removing themselves from work situations that they have reasonable justification to believe present an imminent and serious danger to their safety or health

Employees who justifiably take those actions by notifying their supervisor should be protected from discrimination by removing those barriers as outlined in the OSHMS.

Where this standard and annex refer to employees and their representatives (where representatives exist), the intention is that they should be consulted as the primary means to achieve appropriate participation in the development and implementation of all aspects of the OHSMS. In some instances, it might be appropriate to involve all employees and all representatives.

Employee participation is a key component of an OHSMS. When employees and their representatives are engaged and their contributions are taken seriously, they tend to be more satisfied and committed to the OHSMS, and the system is more effective. Engaging employees and their representatives in dialogue with management and each other about safety and health can lead to improved relationships, better overall communication, improved compliance, and reduced rates of injury, illness, and death. The improved morale translates to greater safety and health results.

Employees and their representatives need to be trained about how the OHSMS works and to evaluate it periodically to determine whether improvements need to be made. The information needs to be presented in a form and language that employees and their representatives easily understand. *(See also A.8.11.4.)*

N **A.9.1** Facility owners should consider inherently safer options when designing or modifying processes that handle combustible particulate solids. Inherently safer design focuses on eliminating or reducing hazards of a process through minimization, substitution, moderation, and simplification, without the addition of procedures or engineered protection systems. The concepts of inherently safer design are described generally in *Inherently Safer Chemical Processes, A Life Cycle Approach,* published by the Center for Chemical Process Safety, and more specifically for combustible dust in "Application of inherent safety principles to dust explosion prevention and mitigation," published in *Process Safety and Environmental Protection.*

Inherently safer design concepts should be used when evaluating options for the design of new processes. When applied early in the design phase of a project, it is often possible to reduce the overall cost of explosion protection by reducing the number of vessels requiring protection or allowing simple, low-cost options such as explosion venting to be used. These concepts can also be applied to facility design to reduce the migration and accumulation of fugitive dust emissions through HVAC and exhaust system design and by minimizing inaccessible horizontal surfaces where dust can accumulate.

Consideration for inherently safer design options should be included in the dust hazards analysis where explosion hazards are identified. The inherently safer design concepts can be used to identify alternative solutions where hazards can be eliminated rather than controlled.

The *Process Safety and Environmental Protection* publication provides descriptions of the principles of inherently safer design that are listed in Table A.9.1. Specific examples of these principles are also summarized in the table.

A.9.2.2 It is preferable for buildings that handle combustible dust to be of either Type I or II construction, as defined by NFPA 220.

Δ **A.9.2.3.1** Chapter 7 provides the process to determine where and whether a dust deflagration hazard exists. Section 9.2 is not intended to cover process equipment such as bins and silos.

A.9.2.3.2 An enclosed means of egress is intended to be an exit separated from other parts of the building or building compartment as used in NFPA *101.* Examples include exit stair enclosures and horizontal exit passageways.

Table A.9.1 Examples of Inherently Safer Design

Principle	Description	Examples
Minimization	Use smaller quantities of hazardous materials when the use of such materials cannot be avoided. Perform a hazardous procedure as few times as possible when the procedure is unavoidable.	Use cutting methods that produce less combustible dust. Reduce the size and number of process vessels that handle combustible dust and produce dust clouds. Design facilities to minimize horizontal surfaces where dust can accumulate.
Substitution	Replace a substance with a less hazardous material (i.e., a completely new substance) or a processing route with one that does not involve hazardous material. Replace a hazardous procedure with one that is less hazardous.	Replace a powder raw material with a liquid formulation or one that is preblended with other noncombustible raw materials used in the process. Use granular or coarse particulate solids instead of dusts. Replace a bucket elevator with a dense phase conveying system. When conveying dry raw materials into a liquid mix vessel, use a liquid eductor to combine the dry and wet ingredients and convey them together.
Moderation	Use hazardous materials in their least hazardous forms (i.e., the same substance but in a safer formulation) or identify processing options that involve less severe processing conditions.	Use powdered materials having a larger particle size distribution or higher moisture content. Perform size reduction processes on moist material prior to drying. Use processing methods that minimize fine dust generation. Change the order of addition of raw materials. For example, add a combustible dust to a vessel prior to adding a flammable solvent.
Simplification	Design processes, processing equipment, and procedures to eliminate opportunities for errors by eliminating excessive use of add-on safety features and protective devices.	Where operator grounding is required, use static dissipative footwear and flooring rather than leg or wrist straps that must be attached prior to performing an operation. Locate dust collectors outdoors in unoccupied areas, where explosion vents can be used instead of more complex protection systems. Perform milling and drying in one step vs. a two-step drying then milling process.

A.9.2.5.1 To the extent feasible and practical from a cost and sanitation standpoint, horizontal surfaces should be minimized to prevent accumulation of dust. Horizontal surfaces that can benefit from a sloped cover include girders, beams, ledges, and equipment tops. Overhead steel I-beams and similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. The additional weight of the box enclosures should be considered in the structural design. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning. One option based on clean design concepts is to construct the building walls so that the structural supports, electrical conduit, and so forth are on the exterior side of the building walls; therefore, the interior building compartment walls are smooth and less likely to collect fugitive dust.

A.9.2.5.3 The space above suspended ceilings is an example of a space that is difficult to access for routine housekeeping. Periodic inspection of such spaces is necessary to ensure accumulations do not result in a deflagration hazard area.

A.9.2.6.3.1 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.9.2.6.3.2 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.9.2.6.3.5 The assertion of separation must recognize the dust accumulation on all surfaces in the intervening distance, including floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures, and walls. Process equipment or ductwork containing dust can also provide a connecting conduit for propagation between accumulation areas. In order to prevent flame propagation across the separation distance, the dust accumulation should be very low. The National Grain and Feed Association study, *Dust Explosion Propagation in Simulated Grain Conveyor Galleries*, has shown that a layer as thin as 1/100 in. is sufficient to propagate flame in a limited expansion connection, such as an exhaust duct or a hallway. In the subject study, the flame propagated for at least 80 ft (24.4 m) in a gallery 8 ft (2.4 m) tall by 8 ft (2.4 m) wide.

A.9.2.6.4.2 Detachment distance is the radial distance between nearest points of two unconnected adjacent buildings.

A.9.3.1 A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with only some, or possibly none, of the prescribed protective measures. More specifically, while ignition source control without consideration of the potential consequences is generally not an accepted primary means of explosion protection, a risk assessment (which by definition requires consideration of the consequences) could determine that ignition source control provides an acceptable level of safety.

A.9.3.3 All three of these types of systems commonly utilize air (or inert gases) to convey the combustible dusts from one location to another. However, each of the systems has unique design, function, and operational characteristics that are significantly different from each other. Each of these types of systems, due to these factors, represents a different level of risk that must be considered when used.

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

A.9.3.3.1.1 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.9.3.3.1.2 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.9.3.3.1.3 The minimum velocity specified in the design for each of these systems differs significantly. Refer to the specific sections for each type of system for that information. For guidance on designing, acquisition, operation, and maintenance of dust collection systems, refer to ACGIH, *Industrial Ventilation: A Manual of Recommended Practice*.

A.9.3.3.1.5 The requirements in 9.3.3.1.5 are applicable to dilute phase pneumatic conveying systems. Dense phase systems require a separate analysis.

A.9.3.3.1.5.2 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.9.3.3.2 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.9.3.3.2.1 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.9.3.3.2.2 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.9.3.3.2.3 Where a raw material or supply transport vehicle or container is connected to a pneumatic conveying system, it is considered a part of the pneumatic conveying system with regard to explosion protection requirements. As such, the requirements of isolation should be evaluated for this type of situation to determine if isolation is needed to protect the conveying system from the raw material supply. It is preferable to locate the filter receivers outside; however, this is often not feasible. Therefore, since deflagration hazards do exist, it is typically necessary to provide the proper protection for deflagration in the filter receiver (AMS) and propagation through the system.

A.9.3.3.3 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.*

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 that results in flows below the minimum required to prevent dust accumulation in the ducts.

Use of manual slide or "blast" gates is not recommended because it can lead to uncontrolled modification of the flow volumes for both a single line and the system as a whole and result in improper balance as described above. Proper design methods inherently ensure minimum airflows and duct velocities without the use of manual slide or blast gates.

Systems have been introduced to incorporate variable-speed fans and automated dampers in dust collection systems serving multiple points of use. These systems can reduce energy use by closing unused branch ducts and reducing fan speed while still maintaining design velocities throughout the system. Proper design of these systems is essential to ensure that reliable operation is achieved under all use conditions. These systems use smaller diameter main ducts to allow adequate conveying velocity to be maintained under normal use conditions. For use as an add-on to existing dust collection systems, the duct system should be redesigned to comply with the requirements of this section. At full use, the smaller main ducts can produce significant pressure drops, therefore the fan should be sized appropriately to accommodate both minimum and maximum use conditions. The design should include the following elements, at a minimum:

(1) The required air volume for each point of use and the minimum velocity for each branch line and duct section between the points of use and the AMS should be specified.
(2) Monitoring systems should be provided at each drop/branch duct to assure minimum design airflow is maintained when the branch is open.
(3) The design should ensure that the required velocity is maintained in all open branches and all duct sections under all use conditions.
(4) The controller should automatically open additional points of use or balance air dampers as necessary to always maintain minimum air velocity in all sub-branches and the main duct.
(5) All gates should be open at startup.
(6) The fan package and AMS used in the system should be compatible with the full performance requirements of the system (all sources open to minimum sources open). Improper selection of these items can result in failure to maintain the required duct velocities.
(7) Alarms should be provided to alert the appropriate personnel when the system fails to provide the required performance.

A.9.3.3.3.1 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.9.3.3.3.2 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.9.3.3.3.3 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.9.3.3.3.4 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.9.3.3.3.5 Examples of operations that under normal operating conditions could generate flames, sparks, or hot material can include grinding, saws, etc. This section is intended to segregate the equipment and operations that are recognized ignition sources from those that are not.

A.9.3.3.3.6 Combustible dusts vary considerably in their characteristics and the type of equipment necessary to separate them from the conveying air or gas stream. While the typical bag or cartridge dust collector (AMS) can be used with most combustible dusts, an exception would be most metal dusts, which can require a scrubber or wet collector. Refer to NFPA 484 for metal dust collection.

A.9.3.3.3.7 The majority of dust collection systems use centrifugal fans for inducing the air flow through the system. Various models are available that will provide the performance characteristics required. Care must be taken to consider the worst-case situation, when the filters are nearly blinded or the scrubber is at maximum differential, as well as the situation where the system is new during start-up.

Δ **A.9.3.3.3.8** The importance of locating the control equipment so that personnel operating the AMS are safe can be illustrated by the following conditions:

(1) Where there is no explosion protection for the dust collector, the personnel operating the AMS would potentially be at risk.
(2) Where the AMS is provided with deflagration venting, NFPA 68 describes the danger zone resulting from the actuation of the vent.

To address the above situations, it is possible to provide blast protection for personnel who must be in the danger zone.

A.9.3.3.4 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.9.3.3.4.1 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.9.3.3.4.2 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.

Hoses of 1.5 in. (38.1 mm) I.D. 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.9.3.3.4.3 Ignition-sensitive materials typically have an MIE of 30 mJ or less.

A.9.3.3.4.4 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 NFPA 484.

A.9.3.4.1.1 See NFPA 68 for guidance on calculating the dirty side volume.

A.9.3.4.3.2 This section is in reference to closed-loop pneumatic conveying systems.

A.9.3.4.3.3 Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as described in Chapter 7 of the ACGIH *Industrial Ventilation: A Manual of Recommended Practice*, should be followed.

A.9.3.4.3.3(2) The system should be designed, maintained, and operated according to accepted engineering practice, and the air–material separator efficiency should be sufficient to prevent dust in the recycled air from causing hazardous accumulations of combustible dust in any area of the building.

A.9.3.4.3.3(3) OSHA has established limits on oxygen concentration in the workplace. Permissible limits range from no lower than 19.5 percent by volume to no higher than 23.5 percent by volume in air. See 29 CFR 1910.146.

N **A.9.3.4.4.6(4)** See NFPA 68.

N **A.9.3.5.3** These systems include pneumatic conveying systems that require relay (booster) fans and product dryers where the fan is an integral part of the dryer.

N **A.9.3.5.4** The production of mechanical sparks is only one possible ignition mechanism from a fan or blower. Frictional heat due to contact between moving parts (i.e., misalignment) or bearing failure can present an ignition source both in the fan and downstream. Additionally, these failure mechanisms can result in a decrease in airflow through the AMD, which can lead to an increase in the combustible dust concentration coincident with the creation of an ignition source.

N **A.9.3.6.2** Whenever a duct size changes, the cross-sectional area changes as well. This change in area causes a change in air velocity in the region of the change, introducing turbulence effects. The net result is that a transition (often called a reducer), with an included angle of more than 30 degrees, represents a choke when the direction of flow is from large to small and leads to localized heating and static electric charge accumulation. When the transition is from small to large, the air velocity drop at the transition is usually enough to cause product accumulation at the transition and the existence of a volume where the concentration of combustible dust is above the MEC. It is strongly recommended that both situations be avoided.

N **A.9.3.6.3** Isolation devices in accordance with 9.7.4 are provided to prevent deflagration propagation between connected equipment. According to 9.7.4, additional protection is indicated when the integrity of a physical barrier could be breached through ductwork failure caused by a deflagration outside the equipment. In some cases, a single equipment isolation device can provide protection in both scenarios if that isolation device is installed at the physical barrier. In other cases, this concern can be addressed by strengthening the duct and supports to preclude failure.

N **A.9.3.9.1.2** Shipping containers can pose a deflagration hazard; however, deflagration protection measures for these units are not always practical. Consideration should be given to deflagration hazards when electing to omit deflagration protection.

N **A.9.3.9.2** Historically, NFPA 654 has required that fixed bulk storage enclosures be constructed of noncombustible materials, which usually meant a metallic material. However, there are some particulates that represent a serious corrosion threat or where contamination from the materials of construction introduces product quality issues, therefore nonmetallic construction is required. The materials of construction for a bulk storage enclosure should not increase the fire protection challenge.

N **A.9.3.9.3.2(2)** Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practicable. Consideration should be given to explosion hazards when electing to omit protection.

N **A.9.3.9.4** Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the amount of surfaces where dust can accumulate.

N **A.9.3.10** Size reduction machinery includes equipment such as mills, grinders, and pulverizers.

N **A.9.3.11** Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

N **A.9.3.12.2.4** High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

N **A.9.3.14** It is recommended that bucket elevators be located outside of buildings whenever practicable.

N **A.9.3.14.4.1** Belt alignment monitoring devices are recommended for all elevator legs. Bearing monitoring systems are recommended for head, tail, and bend (knee) pulley bearings on elevator legs.

N **A.9.3.14.4.2** Where conductive buckets are used on nonconductive belts, bonding and grounding should be considered to reduce the hazards of static electricity accumulation. *(See NFPA 77 for more information.)* ISO 284, *Conveyor Belts — Electrical Conductivity — Specification and Test Method,* or DIN 22104, *Antistatic Conveyor Belts — Specification and Method of Test,* can be used to evaluate conductivity. ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type,* or ISO 340, *Conveyor Belts — Laboratory scale flammability characteristics — Requirements and test method,* are standards that can be used to evaluate fire resistance.

N **A.9.3.14.4.4** Where it is desired to prevent propagation of an explosion from the elevator leg to another part of the facility, an explosion isolation system should be provided at the head, boot, or both locations.

N **A.9.3.14.5.1** The motor selected should not be larger than the smallest standard motor capable of meeting this requirement.

N **A.9.3.15** Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.

N **A.9.3.15.2.1** Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

N **A.9.3.17** Dryers include tray, drum, rotary, fluidized bed, pneumatic, spray, ring, and vacuum types. Dryers and their operating controls should be designed, constructed, installed, and monitored so that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained.

N **A.9.3.17.1.7** The maximum safe operating temperature of a dryer is a function of the time–temperature ignition characteristics of the particulate solid being dried as well as of the dryer type. For short time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature.

However, if particulate solids accumulate on the dryer surfaces, the operating temperature should be maintained below the dust layer ignition temperature. The dust layer ignition temperature is a function of time, temperature, and the thickness of the layer. It can be several hundred degrees below the dust cloud ignition temperature. The operating temperature limit of the dryer should be based on an engineering evaluation, taking into consideration the preceding factors.

The dust cloud ignition temperature can be determined by the method referenced in U.S. Bureau of Mines RI 8798, "Thermal and Electrical Ignitability of Dusts" (modified Godbert-Greenwald furnace, BAM furnace, or other methods). The dust layer ignition temperature can be determined by the U.S. Bureau of Mines test procedure given in Lazzara and Miron's report, "Hot Surface Ignition Temperatures of Dust Layers."

A.9.4.1 It is not always possible or practical for existing facilities to be in compliance with the new provisions of a standard at the effective date of that standard. Therefore, "retroactivity" in 9.4.1 means that a plan should be established to achieve compliance within a reasonable time frame.

A.9.4.2 A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with only some, or possibly none, of the prescribed protective measures. More specifically, while ignition source control without consideration of the potential consequences is generally not an accepted primary means of explosion protection, a risk assessment (which by definition requires consideration of the consequences) could determine that ignition source control provides an acceptable level of safety.

A.9.4.4.2 Consensus standard hot surface dust layer ignition temperature tests include ASTM E2021, *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.9.4.5.2 The intent of this requirement is to address bearings that can have accumulations of dust on them or be in a suspended dust cloud. The concern is that if the bearing overheats it can present an ignition source to the dust cloud or the dust layer.

Such equipment can include, but is not limited to, the following:

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

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

A.9.4.5.4 The risk assessment should include the potential for propagation of an explosion from an unmonitored unit.

A.9.4.6.1 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 to remove the dust by developing proper housekeeping procedures. If the release of dust from equipment, cannot be prevented or the dust cannot be cleaned up, then that area might be an electrically classified area. NFPA 499 can be used for guidance to supplement the criteria in Article 500.5 of *NFPA 70.* This guidance depends on a determination of the combustibility of dust in a particular area, the ignitibility properties of the dust, and the nature of possible dust cloud formation and dust layer accumulations within and outside the electrical equipment near the dusts. NFPA 499 is a good source for guidance on identifying Class III areas.

The user of this document should be aware that the dust layer accumulation criteria in Articles 500–505 of *NFPA 70* and NFPA 499 is intended to address electrical ignition hazards due to overheating or shorting of electrical equipment. The threshold housekeeping dust accumulation criteria in this standard are based on a dust flash-fire or dust deflagration hazard. These differing criteria can lead to different layer depth requirements. It is possible that even where electrically classified equipment is installed the area can still be considered a flash-fire or deflagration hazard.

A.9.4.6.1.1 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.9.4.6.4 NFPA 70B contains recommendations on the development of an effective electrical equipment maintenance program. Article 502.15 of *NFPA 70* contains descriptions of seals for electrical enclosures and fittings. The description includes a requirement that sealing fittings be accessible. This requirement is intended to include cabinets and other enclosures such as MCCs, control panels, and main switch gear, but not conduit, raceways, junction boxes, or other similar equipment.

Δ **A.9.4.6.5** Article 502 of *NFPA 70* permits the use of Zone 20 equipment installation in a Class II, Division 1, location for the same dust. If the dust is a metal dust and not a combustible metal dust according to the test methods for Group IIIC, based on a conductivity criterion, this would potentially have equipment identified for Group IIIB (suitable for nonconductive dusts) installed in a Class II, Division 1, Group E, location. This would definitely not be appropriate. Contrary to the general statement in 506.6(A) of *NFPA 70,* a metal dust could be in Division Group E but not be conductive enough to be in Zone Group IIIC.

Another discrepancy in the requirements for zone classification versus division classification is that Article 506 of *NFPA 70* provides no limitation on the designation of Zone 22 locations for combustible metal dusts. Under the division system in 500.5(C)(1)(3) of *NFPA 70*, where there is Group E metal dust in hazardous quantities, the location would be classified as Division 1 and would not be permitted to be classified as Division 2. Under the zone system, the less protective Zone 22 could be chosen.

Both of these discrepancies are nonconservative in comparison to the division classification system. While *NFPA 70* has established a framework for the use of zone classification for dusts, these nonconservative discrepancies in the boundaries between dust groups and area classification zones/divisions must be resolved before applying these concepts to industrial situations. The NFPA EECA committee had previously coordinated the boundaries between zone and division for gases but has not yet addressed this significant issue for dusts. Until these discrepancies can be addressed, NFPA 652 should not permit the application of zone classification for combustible dusts in industrial occupancies.

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

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

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

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

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

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

N **A.9.4.7.1.2(1)** This requirement is intended to prevent ignition of hybrid mixtures or flammable gas/vapor atmospheres by brush discharges from nonconductive surfaces.

N **A.9.4.7.1.2(2)** This requirement is intended to prevent ignition of combustible dusts by the isolation of conductive particulate solids where they can accumulate charge and create capacitive spark discharges to grounded conductive objects.

N **A.9.4.7.1.2(3)** This requirement is intended to prevent ignition of combustible dusts by capacitive sparks from isolated process equipment.

A.9.4.7.1.2(4) This requirement is intended to prevent ignition of combustible dusts by propagating brush discharges. Pneumatic conveying is an example of a process operation that can generate high surface charging.

A.9.4.7.1.3 This requirement is intended to prevent ignition of combustible dusts, flammable gas/vapor atmospheres, or hybrid mixtures by capacitive sparks from isolated process equipment. Where the bonding and grounding system is all metal, resistance in continuous ground paths typically is less than 10 ohms. Such systems include those having multiple components. Greater resistance usually indicates that the metal path is not continuous, usually because of loose connections or corrosion. A permanent or fixed grounding system that is acceptable for power circuits or for lightning protection is more than adequate for a static electricity grounding system.

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

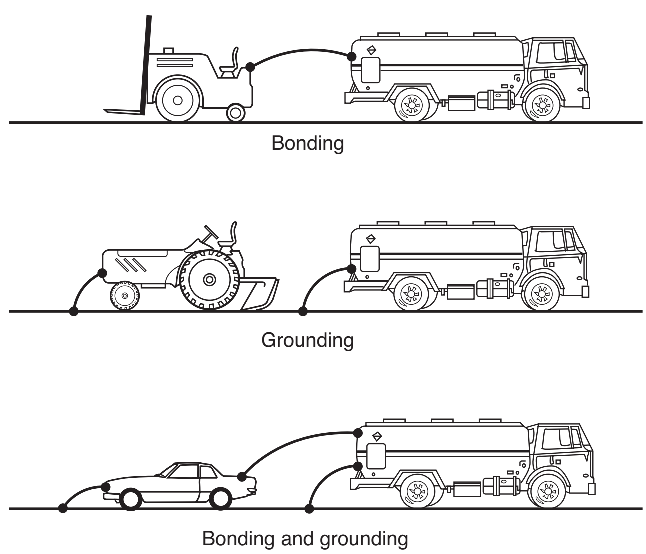

FIGURE A.9.4.7.1.3 Bonding and Grounding.

N **A.9.4.7.1.4** In order to properly specify a flexible connector for combustible dust service, it is necessary to know the end-to-end resistance. The end-to-end resistance is typically not specified by the suppliers of flexible connectors. This makes it necessary for the user to measure it. ISO 8031, *Rubber and plastics hoses and hose assemblies — Determination of electrical resistance and conductivity*, provides methods to determine the end-to-end resistance. For convenience, the following is a brief description of a similar procedure:

(1) It is preferred to measure the actual flexible connector to be used, but if it is too long for this to be practical, a shorter length (for example, 6 in. to 24 in.) can be used. The measured end-to-end resistance per unit length can then be multiplied by the total flexible connector length to get the overall flexible connector end-to-end resistance.
(2) The flexible connector should be placed on a nonconductive surface, such as a rigid sheet of PTFE, polyethylene, or polypropylene. It is important that neither the flexible connector or megohm meter metal connections are touched by the operator's bare skin during the measurement as this will short the circuit. In addition, the rigid polymer sheet and flexible connector should be dry during the measurement.
(3) The leads on a megohm meter should be contacted on the inside surface of the flexible connector at each end. This should be done at several points on the inside surface to ensure that a consistent reading is obtained. Care should be taken to make measurements at the greatest distance from any supporting wires in the flexible connector to avoid measuring the resistance across the wire. The readings should be taken at approximately 500 V.

N **A.9.4.7.1.4.1** Flexible connectors wear out over time. The intent of this statement is that existing connectors would be replaced with compliant flexible connectors at the end of their service life.

A.9.4.7.1.4.3 Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic discharge, do not produce discharge energies in excess of 2000 mJ.

A.9.4.7.2.1 The limit on particulate discharge rates is due to concern about possible generation of charge accumulation during rapid transport and the subsequent potential for a bulking brush discharge. From Britton, Section 2-6.3.2 in *Avoiding Static Ignition Hazards in Chemical Operations*, the minimum size of a container for bulking brush discharges to occur has not been established, but is probably about 1 m^3.

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

A.9.4.7.2.1(1) The maximum electrostatic discharge energy from a bulking brush discharge energy is about 20 mJ. *(See Britton, Avoiding Static Ignition Hazards in Chemical Operations.)*

A.9.4.7.2.1(2) The threshold high electrical volume resistivity is usually considered to be 1.0×10^{10} ohm-m. Additional information on electrical resistivity can be found in *Avoiding Static Ignition Hazards in Chemical Operations* by L. Britton, with the values for common materials listed in Appendix B.

A.9.4.7.2.2 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.9.4.7.2.2(1) The limit on material transport or discharge rates for large particulates that contain no fines into a vessel that contains fines is due to the potential of dust clouds that could still be present in the headspace of the vessel from the previous loading of the fine material or from the influx of the large material causing the fine material to be suspended into the headspace and then subsequently ignited by a bulking brush discharge.

A.9.4.7.2.2(2) The limit on material transport or discharge rates for large particulates when fine material is added to the vessel later is due to the possibility of a bulking brush discharge occurring in the vessel and the introduction of fine material could create a combustible atmosphere and be ignited by the bulking brush discharge. The time required for any charge on the large particulate to dissipate depends on the material properties, dimensions of the vessel, and a variety of other factors. A hazard assessment could be performed to determine the time after the large particulate has been added in which it would be safe to add the fine material.

A.9.4.7.2.3 In *Electrostatic Hazards in Powder Handling*, Glor recommends the following limitations on hopper/silo/equipment filling rates for high-resistivity ($> 10^{10}$ ohm-m) powders that can produce bulking brush discharges. In the case of powders in the presence of granules with a diameter of several millimeters, Glor recommends the filling rate be less than 2000 to 5000 kg/hr (0.56 to 1.4 kg/s). For particles with diameters larger than 0.8 mm, he recommends maximum filling rates of 25,000 to 30,000 kg/hr (6.9 to 8.3 kg/s).

A.9.4.7.3 NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of noncombustible residues do not interfere with continuity.

A.9.4.7.3.1 The user should expect that activities such as pouring, unloading, and transferring dusts can lead to the development of an ignitible atmosphere above the settled material in the receiving vessel.

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

Δ **A.9.4.7.3.2(2)** Based on information in Britton, *Avoiding Static Ignition Hazards in Chemical Operations*, the maximum reasonable discharge energy from a person is estimated to be approximately 25 mJ. Where the MIE of the dust cloud is greater than 30 mJ, personnel grounding provides no risk reduction. MIE is dependent on particle size, so it is important to determine the MIE value on the particle size distribution that is likely to remain airborne during the operation. Since large particles will quickly fall out of suspension, the sub-75 μ fraction of the material (or material passing through a 200-mesh sieve) is typically tested for this purpose. Where a bulk material includes larger particles, the sub-75 μ MIE might be significantly lower than the bulk material MIE. ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, is the test method for determining particulate and dust MIE.

A.9.4.7.4 A more detailed description of FIBC ignition hazards can be found in IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*.

A.9.4.7.4.1 Induction charging of ungrounded conductive objects, including personnel, should be addressed as part of the dust hazards analysis. The DHA should also consider that higher rates of transfer into and out of the FIBC increase the rate of charge generation. Consideration should also be given to the possibility of surface (cone) discharges while the FIBC is being filled, regardless of FIBC type.

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

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N **A.9.4.7.4.2** Type A FIBCs are capable of producing propagating brush discharges that are capable of igniting combustible dusts and flammable vapors/gases. Type A bags are capable of producing brush discharges that are capable of igniting flammable vapors/gases. Type A FIBCs can allow conductive particulate solids to become isolated conductors, leading to capacitive spark discharges.

N **A.9.4.7.4.2.2** For this application, conductive particulate solids typically are those materials having bulk resistivity less than 10^6 ohm-m.

N **A.9.4.7.4.3** Type B FIBCs are capable of producing cone (bulking brush) discharges across the full width of the FIBC with maximum discharge energies of ~3 mJ. These discharges are capable of igniting flammable vapors/gases and combustible dusts with MIE < 3 mJ. Type B bags are capable of producing brush discharges that are capable of igniting flammable vapors/gases. Type B FIBCs can allow conductive particulate solids to become isolated conductors, leading to capacitive spark discharges.

N **A.9.4.7.4.4** Type C FIBCs are capable of producing capacitive spark discharges if the grounding tab is not connected. Type C FIBCs are not capable of producing brush or propagating brush discharges, but could be capable of producing cone discharges across the half-width of the bag. Some Type C FIBCs have an internal coating that can isolate conductive particulate solids from ground, producing the potential for capacitive spark discharges from the conductive material to the grounded conductive elements of the bag. Per IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, Type C FIBCs are permitted to be used for Zone Group IIA and IIB gases but not Group IIC.

N **A.9.4.7.4.5** Type D FIBCs use low energy corona discharges to dissipate static charges from the bag surface. Corona discharges are capable of igniting flammable gases or vapors with MIE less than 0.14 mJ. Type D FIBCs are not capable of producing brush or propagating brush discharges, but could be capable of producing cone discharges across the half-width of the bag. Per IEC 61340-4-4, Electrostatics — Part 4-4: *Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, Type D FIBCs are permitted to be used for Zone Group IIA and IIB gases but not Group IIC.

N **A.9.4.7.4.5.1** Type D bags function by corona discharge. Metals or other conductive particulate solids could require additional precautions because, if the particulate is isolated and becomes charged, incendiary sparks could occur during rapid filling and emptying operations. IEC TS 60079-32-1 gives guidance on additional precautions that could be necessary. A risk assessment referencing IEC TS 60079-32-1 could be performed to support the use of Type D FIBCs for conductive particulate solids.

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

A.9.4.7.4.7 In special cases it might be necessary to use a type of FIBC that is not permitted for the intended application based on the requirements of 9.4.7.4. For such cases, it might be determined that the FIBC is safe to use provided that filling or emptying rates are restricted to limit electrostatic charging. In the case of conductive combustible particulate solids, the use of a Type A FIBC might be acceptable provided that the maximum ignition energy from the FIBC or charged product within it is less than the MIE of the combustible particulate solids.

Δ **Table A.9.4.7.4.6 Use of Different Types of FIBCs**

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

Notes:

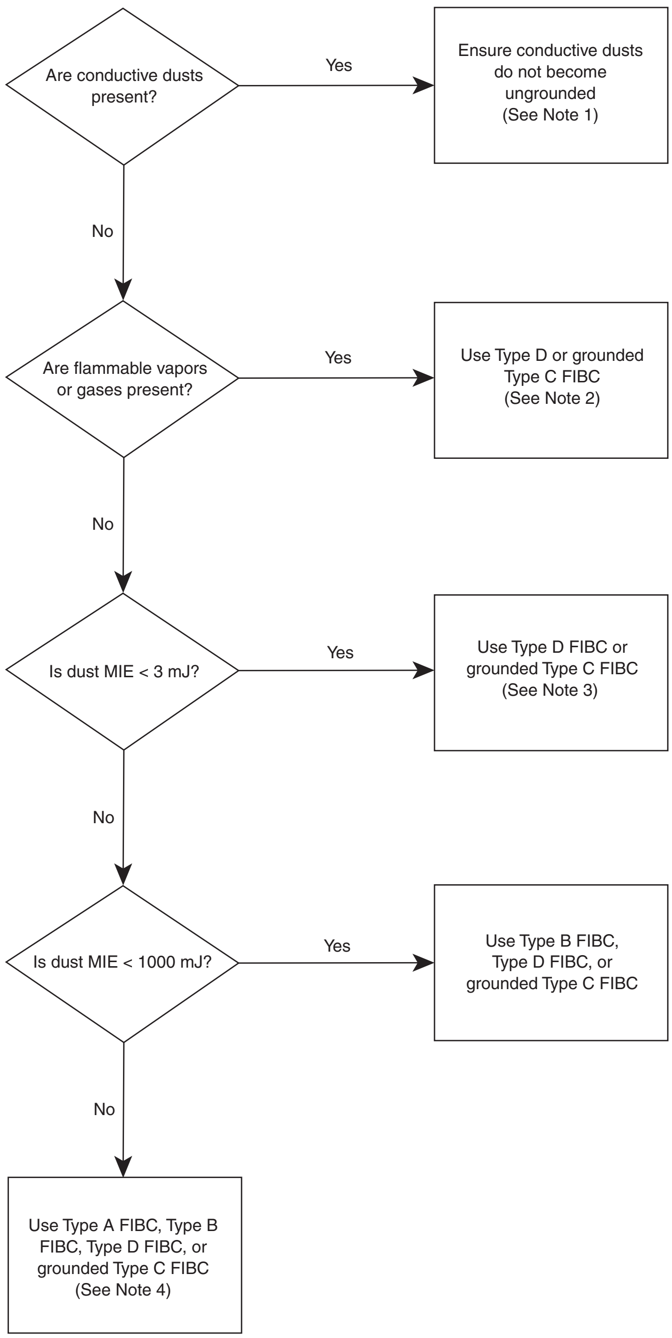
(1) Additional precautions usually are necessary when a flammable gas or vapor atmosphere is present inside the FIBC, for example, in the case of solvent wet solids.

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

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

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

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



Note 1: Conductive dusts can produce spark discharges if allowed to be isolated from ground. Grounded Type C FIBCs can provide adequate grounding, but some Type C FIBCs have internal coatings or liners that can allow conductive dusts to remain isolated. A risk assessment is recommended prior to handling conductive dusts in FIBCs.

Note 2: Do not use Type D FIBCs for flammable vapors/gases with MIE < 0.14 mJ.

Note 3: Type A or B FIBCs can allow cone discharges to occur across the full width of the FIBC, with an effective energy up to 3 mJ.

Note 4: Type A FIBCs have the potential to produce propagating brush discharges with effective energy of ~1000 mJ.

N **FIGURE A.9.4.7.4.6 FIBC Selection Decision Tree.**

A.9.4.7.5.1 Conductive containers are generally made from either metal or carbon-filled plastic having a volume resistivity less than 10^6 ohm-m.

Δ **A.9.4.7.5.2** Induction charging of ungrounded conductive objects, including personnel, should be addressed as part of the risk assessment and dust hazards analysis when the use of nonconductive RIBCs is being considered. The risk assessment should also consider that higher rates of transfer into and out of the RIBC increase the rate of charge generation, which could result in the brush discharges, propagating brush discharges, or surface (cone) discharges while the RIBC is being filled. For additional information on these phenomena, refer to NFPA 77.

A.9.4.8.1 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.9.4.9.2 Diesel-powered front-end loaders suitable for use in hazardous locations have not been commercially available.

A.9.4.10.1 The maximum safe operating temperature of a dryer is a function of the time–temperature ignition characteristics of the particulate solid being dried as well as of the dryer type. For short-time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature.

However, if particulate solids accumulate on the dryer surfaces, the operating temperature should be maintained below the dust layer ignition temperature. The dust layer ignition temperature is a function of time, temperature, and the thickness of the layer. It can be several hundred degrees below the dust cloud ignition temperature. The operating temperature limit of the dryer should be based on an engineering evaluation, taking into consideration the preceding factors.

Δ **A.9.4.11.1** Particulate materials that are known to self heat under various circumstances include, but are not limited to, resinous sawdust, sewage sludge, powdered metals, wet agricultural materials, low rank coal, activated carbon charcoal, and bagasse. Tabulations of materials prone to self-heating can be found in the following references: *NFPA Fire Protection Handbook*; Bowes, *Self-Heating: Evaluating and Controlling the Hazards;* U.S. Department of Energy handbook, *Primer on Spontaneous Heating and Pyrophoricity;* and Babrauskas, *Ignition Handbook Database*. Test methods to assess the propensity for self-heating, and to determine critical storage pile sizes and time to self heat are also described in Bowes and Babrauskas. Methods of self-heating detection include temperature monitors within the pile or silo and carbon dioxide monitors in the silo. Self-heating management can be accomplished through timely processing of the affected particulate through the storage system before self-heating can become an issue.

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

A.9.4.12.2 Methods that are commonly used to remove foreign material include the following:

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

A.9.4.12.4 In the case of size reduction equipment with continuous screened outlets, high speeds that can generate friction and impact sparks are considered to be tip speeds in excess of 10 m/sec. In the case of blenders and other completely enclosed equipment processing material in batches, high speeds are considered to be blade tip speeds in excess of 1 m/sec.

A.9.6.1 Other means to control fugitive dust emissions can include established housekeeping procedures where the fugitive emissions do not approach the MEC, and the housekeeping schedule does not allow settled dust accumulations to exceed the threshold housekeeping dust accumulation limit.

A.9.6.2 Use of liquid dust suppression methods for dust control involves the use of fine, atomized, or fogging liquid sprays to limit the emission of combustible dusts. By using an atomized or fogging spray of liquid, which is often just water, dust can be controlled and prevented from accumulating in surrounding areas. This method is also often used in place of standard dust collection for both economical and operational reasons.

N **A.9.6.3** These devices are used to continuously dislodge dust from hard-to-reach building surfaces such as roof structural members, lighting, and elevated ductwork. The fans used typically rotate through a 360 degree arc and oscillate up and down to keep dust from the surfaces within reach of the fan discharge. Large rooms require multiple fans for adequate coverage.

These systems are most effective for facilities with high ceilings where light, easily entrained dusts or fibers are handled.

N **A.9.6.3.8** These systems are intended to reduce the housekeeping burden on elevated surfaces. However, they do not remove dust from the facility. The material is simply relocated to lower surfaces where it is easier to clean using standard housekeeping procedures. These systems might increase the required housekeeping frequency on lower surfaces, and might increase the amount of dust carried into the building HVAC system.

N **A.9.6.3.9** These systems should not be used where they can relocate dust into concealed spaces where the dust can accumulate and pose a deflagration hazard.

A.9.7.3.1 Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practical. Consideration should be given to explosion hazards when electing to omit protection; 8 ft^3 (0.2 m^3) is roughly the size of a 55 gal (208.2 L) drum.

A.9.7.4 A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources.

The requirement of 9.7.4.1 might not be applicable where all of the following conditions are met:

(1) The material being conveyed is not a metal dust, an ST-3 dust (K_{St} > 300 bar-m/sec), or a hybrid mixture.
(2) The connecting ductwork is smaller than 4 in. (100 mm) nominal diameter and greater than 15 ft (5 m) in length.
(3) The conveying velocity is sufficient to prevent accumulation of combustible dust in the duct.
(4) All connected equipment is properly designed for explosion protection by means other than deflagration pressure containment.
(5) The upstream work areas do not contain large quantities of dust that can be entrained by a pressure pulse from an explosion in the AMS.

When managing the hazard of propagation via small duct, one can develop a performance equivalent alternative in accordance with Chapter 6.

Flame spread via propagation inside ducting or piping is somewhat unpredictable for dusts. Tests have shown that propagation is much less likely under certain conditions. Piping less than 4 in. (100 mm) in diameter is less likely to provide a conduit for flame spread than larger diameter piping, although experiments have shown propagation in still smaller diameter piping.

FSA conducted flame propagation tests in a system comprising two interconnected and vented 35 ft^3 (1 m^3) vessels. Experiments were carried out with pipe diameters of 1.1 in., 1.6 in., and 3.2 in. (27 mm, 42 mm, and 82 mm), all diameters of less than 4 in. (100 mm). Corn starch (K_{St} = 200 bar-m/sec) and wheat flour (K_{St} ≈ 100 bar-m/sec) were used as fuels. Even with a small pipe diameter of 1.1 in. (27 mm) and with wheat flour (K_{St} ≈ 100 bar-m/sec) used as test dust, there was a flame propagation through a pipe length of at least 39 ft (12 m) in length.

For interconnected vessels that are relatively close together, measures to reduce P_{red} for each interconnected vessel, taking into account that propagation could occur, would eliminate the need for isolation techniques.

Dense phase pneumatic transfer [air velocities down near 600 fpm (183 m/min), and solids loading ratios greater than 30] is also much less likely to provide a conduit for flame spread propagation than for dilute phase pneumatic transfer [air velocities in the region of 2200 fpm to 3600 fpm (672 m/min to 1098 m/min), and solids loading ratios not greater than 15]. In Pineau and Ronchail's report, "Propagation of Dust Explosions in Ducts," it is stated that it is not uncommon for propagation to occur as little as one in 10 times in controlled experiments for 5.9 in. (150 mm) piping, even for dilute phase systems. However, recent testing has shown that propagation is more likely with dust concentrations in the lean region. Metal dusts are more likely to propagate deflagrations. For organic dusts, where small diameter pipes with dense phase transfer are utilized, the need for isolation techniques could be obviated if the hazard analysis is acceptable to the AHJ.

Factors for evaluation of isolation between equipment and work areas include, among others, the anticipated P_{red} for the related process equipment, the diameter and length of the connecting air duct, the K_{St} of the dust, and the quantity of dust in the work area that can be entrained by a pressure pulse from a deflagration in the related process equipment. Zalosh and Greenfield (2014) have shown that the probability of propagation decreases exponentially with increasing values of the parameter $L/[(K_{St}-K_{min})(d-d_{min})]$, where L is the duct or pipe length between equipment, d is the duct or pipe diameter, K_{min} is the minimum K_{St} required for propagation in short pipes (configuration dependent), and d_{min} is the minimum diameter for propagation in short pipes (depends on P_{red}). For more information, see "Dust explosion propagation and isolation," by Jerome Taveau in the *Journal of Loss Prevention in the Process Industries*.

See references in D.1.2.10 for additional information.

A.9.8.1.2 Fire protection systems for operating enclosures are often overlooked. Paragraph 9.8.1.2 is intended to help the user determine when fire protection systems are warranted. The design of the fire protection system should consider the hazards of the materials present. For example, water-based protection systems are generally not appropriate for combustible metals, as described in NFPA 484.

Δ **A.9.8.1.2(1)** Manual fire fighting poses an unacceptable risk to facility personnel and emergency responders. The evaluation of the risk to facility personnel and fire fighters should be made based on discussions and review of the hazard assessment described in Chapter 7. Such a system(s) is (are) needed to meet the objectives stated in Section 4.2.

Δ **A.9.8.1.2(2)** The potential effectiveness of manual fire fighting should be assessed by experienced fire fighting personnel after reviewing the hazard assessment documentation developed in accordance with Chapter 7 requirements.

A.9.8.2.1 Pneumatic conveying, centralized vacuum, and dust collection systems that move combustible particulate solids can be classified as water compatible, water incompatible, or water reactive. Inasmuch as water is universally the most effective, most available, and most economical extinguishing medium, it is helpful to categorize combustible particulate solids in relation to the applicability of water as the agent of choice. For details on use of water as an extinguishing agent, see Annex F of NFPA 654.

A.9.8.2.4 In the case of automatic suppression systems, low momentum applications can be achieved by using small water drops or extinguishing powders and by avoiding accumulations of combustible particulate in the immediate vicinity of the discharge nozzle. In the case of dry pipe automatic sprinkler systems, it is particularly important to prevent fugitive combustible dust accumulations on or near the dry pipe because the initial discharge of compressed air can produce a suspended dust cloud and the potential for a flash fire or explosion.

In the case of manual application of extinguishing agents, 9.8.3.2 provides additional guidance on avoiding dust cloud formation during agent application.

A.9.8.3.2 Extreme care should be employed in the use of portable fire extinguishers in facilities where combustible dusts are present. The rapid flow of the extinguishing agent across or against accumulations of dust can produce a dust cloud. When a dust cloud is produced, there is always a deflagration hazard. In the case of a dust cloud produced as a result of fire fighting, the ignition of the dust cloud and a resulting deflagration are virtually certain. Consequently, when portable fire extinguishers are used in areas that contain accumulated combustible dusts, the extinguishing agent should be applied in a manner that does not disturb or disperse accumulated dust. Generally, fire extinguishers are designed to maximize the delivery rate of the extinguishing agent to the fire. Special techniques of fire extinguisher use should be employed to prevent this inherent design characteristic of the fire extinguisher from producing an unintended deflagration hazard.

A.9.8.4.2.1 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.9.8.4.2.2 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.9.8.5.1 A risk assessment should consider the presence of combustibles both in the equipment and in the area around the process. Considerations should include the combustibility of the building construction, the equipment, the quantity and combustibility of process materials, the combustibility of packaging materials, open containers of flammable liquids, and the presence of dusts. Automatic sprinkler protection in air–material separators, silos, and bucket elevators should be considered.

A.9.8.5.2 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.

Annex B Dust Hazards Analysis — Example

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

B.1 Introduction. This annex is intended to illustrate one example of how to develop a DHA for a facility. Other methods include, but are not limited to, "what-if" analysis, failure mode and effects analysis, fault tree analysis, and HAZOP. Additional guidance on performing a DHA is available in the NFPA *Guide to Combustible Dusts* and in the AIChE *Guidelines for Hazard Evaluation Procedures*. It is not the intent of this standard to require users to apply the PHA provisions of OSHA regulations in 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," in developing a DHA. The example is intentionally vague to allow users to match the complexity and extent of the analysis to the complexity and extent of the facility and its process.

B.2 Purpose. The purpose of a DHA is to identify hazards in the process and document how those hazards are being managed. The hazards addressed by this standard are the fire, deflagration, and explosion hazards of combustible dusts. There might be other hazards associated with a process such as industrial hygiene that are not covered in this annex. However, the process of analysis outlined in this annex could be applied to other hazards.

B.3 Overview.

B.3.1 A DHA is a detailed analysis and documentation of the process and the facility housing the process.

B.3.2 Each part of the process system is considered for potential deflagration hazard.

B.3.2.1 Where the hazard is managed, the means by which it is being managed is documented.

B.3.2.2 Where the hazard is not being managed, possible means by which it can be managed should be identified as well as any critical data or parameters that must be quantified before a management method can be applied.

B.3.3 Each building or building compartment is considered for potential deflagration hazard.

B.3.3.1 Where the hazard is managed, the means by which it is being managed is documented.

B.3.3.2 Where the hazard is not being managed, possible means by which it can be managed should be identified as well as any critical data or parameters that must be quantified before a management method can be applied.

B.3.4 The potential for a dust deflagration should be based upon the potential for all four necessary and sufficient conditions for a deflagration to exist at the point of consideration concurrently.

B.3.4.1 The conditions for a deflagration are as follows:

(1) Particulate of a dimension small enough to propagate a deflagration flame front
(2) Means of suspending or dispersing the particulate in air or other oxidizing atmosphere
(3) Sufficient quantity of particulate to achieve the minimum explosible concentration
(4) Competent source of ignition

B.3.4.2 As a general rule in NFPA standards, there is an assumption that ignition will occur. However, some situations of ignition source control could be determined acceptable by taking into account the consequences (i.e., risk analysis). If a deflagration is possible, the results should be managed in such a way that the objectives of the standard are met.

B.3.4.3 The DHA should classify locations into three general categories:

(1) Not a hazard
(2) Might be a hazard
(3) Deflagration hazard

This will help the owner/operator prioritize management of the hazards. Additionally, it will identify the locations where more information is necessary before a definitive determination can be made.

B.3.4.4 The individual assessments in the DHA are brought into a cohesive understanding of the hazards associated with the overall operations as well as the individual components.

B.3.4.5 A well-documented risk assessment that is acceptable to the authorities having jurisdiction can be used to supplement the DHA to determine what protection measures are to be used.

B.4 Sample DHA.

B.4.1 This example is intended to provide the user with some of the deliberation that can be used in performing a DHA. It is not intended to cover all the methods, situations, and processes that might be encountered in facilities that handle combustible particulate solids. In particular, it does not account for fire hazards that are independent of deflagration hazards. Refer to Figure B.4.1 for the process used in this example.

B.4.2 This process receives wood chips via rail car and over the road trailer truck. The wood chips come from hogging (grinding) operations at other facilities. The chips are unloaded and conveyed pneumatically to a storage silo. From the storage silo the chips are conveyed via screw conveyor to a size reduction mill. The mill discharges particulate to a transport fan, which sends the particulate to a set of screens. The material that is sufficiently fine passes through the screens and proceeds via the product screw to some other location. The particles that exceed the size specification are sent back through the mill.

B.4.3 Dust collection is provided for this process. The dust collection system receives the exhaust from the cyclone, ullage space of the silo, out-feed screw conveyor, screens, and the product screw conveyor. The cleaned air is returned to the building interior.

B.4.4 Each and every process component should be evaluated, including ducts, conveyors, silos, bunkers, vessels, fans, and other pieces of process equipment. Each point along the process should be described, and hazards at each point should be identified. Remedial measures for each hazard should be identified and documented. The means by which the hazard should be managed is then determined. Usually the relevant occupancy standard will provide options. The process and process equipment will often determine which option is most appropriate.

B.4.5 Each of the following points in the process in which a deflagration could occur is identified:

(1) Each duct
(2) Each conveyor
(3) Each silo, bunker, or other vessel
(4) Each fan
(5) Each piece of process equipment

Usually a volume exemption of 8 ft^3 (0.2 m^3) or less is applied to enclosed pieces of process equipment in deflagration hazard management. This exemption comes from the difficulty in designing deflagration suppression for vessels that small, as well as the modest hazard such small vessels represent. Assuming an 8-to-1 volumetric expansion from a dust deflagration, an 8 ft^3 (0.2 m^3) enclosure will yield a fireball volume of approximately 64 ft^3 (1.8 m^3), the volume of a sphere with a 10 ft (3 m) diameter. This is the estimated maximum extent of the fireball volume. This fact can be used to select the parts of the process system to be considered in the analysis. If a piece of process equipment includes a volume less than 8 ft^3 (0.2 m^3), it should be documented as such in the DHA.

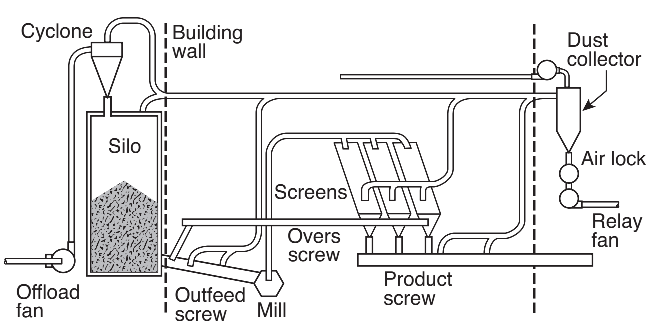


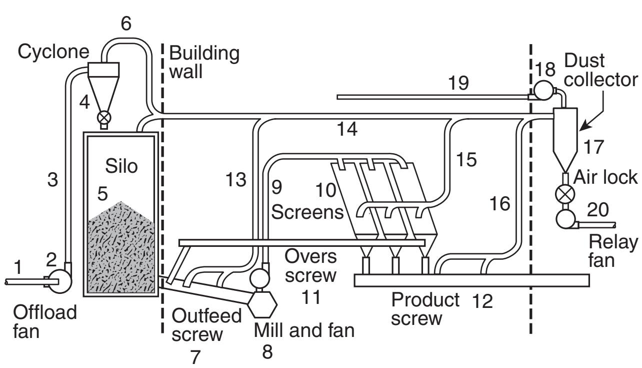
FIGURE B.4.1 An Example Process. ***(Source: J. M. Cholin Consultants, Inc.)***

The DHA also considers the building compartment(s) where combustible particulates are being handled or processed. These compartments should be evaluated for both deflagration hazard and building rupture and collapse (explosion) hazard. *(See Figure B.4.5.)*

B.4.5.1 Location 1: Offload Duct to Offload Fan.

B.4.5.1.1 Is the particulate deflagrable (explosible)? The ability to propagate a deflagration flame front is the artifact of material chemistry – how much heat is released per unit of mass when it burns – and particle size. What are the deflagration metrics for this material? Has the material been tested for MEC, MIE, K_{St} and P_{max}? Depending upon the material, other data might be necessary.

Currently, ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds,* includes a screening test to determine if the particulate is capable of propagating a deflagration. However, the average particle size is often used as a first order estimate. Some standards use a nominal average particle size of 500 μm as the dividing line. Wood hogs generally have screens that produce particulates between 0.25 in. (6.4 mm) and 1.00 in. (25.4 mm) in largest particle dimension. This is substantially greater than 500 μm. 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.



1 Process input
2 Offload fan
3 Duct from fan to cyclone
4 Cyclone
5 Silo
6 Duct
7 Outfeed screw conveyor
8 Mill and discharge fan
9 Discharge duct to screens
10 Screens
11 Screw conveyor
12 Product screw conveyor
13 Duct
14 Duct
15 Duct
16 Duct
17 Dust collector
18 Fan
19 Duct for return air
20 Relay fan

Δ **FIGURE B.4.5 An Example Process.** ***(Source: J. M. Cholin Consultants, Inc.)***

While sieve analysis cannot be relied upon as the sole hazard identification means, it is useful for informing the analysis. There isn't yet reported research that serves as a basis for establishing a percentage of fine particulate versus coarse particulate sufficient to propagate a flame front.

B.4.5.1.2 Is the particulate suspended in air? Since a fan is used to suck this material through a duct the answer is yes.

B.4.5.1.3 Is there sufficient concentration to propagate a flame front? At this point in the process, a sieve analysis of the process stream could provide some additional information. If the dust concentration exceeds the MEC of the dust, then there is the potential for flame propagation. However, large particles are quenching surfaces and inhibit flame propagation. In the mixture used in this example it is not likely.

B.4.5.1.4 Are there competent igniters available? Yes. The material could have been ignited as it was loaded into the railcar or truck trailer. (This has happened.) Tramp metal could be present in the particulate that can strike sparks as it hits the wall of the duct.

B.4.5.1.5 What hazard management is in place? Is there metal detection, spark detection, bonding and grounding, or other hazard management means in place?

B.4.5.2 Location 2: Offload Fan.

B.4.5.2.1 Is the particulate deflagrable (explosible)? See B.4.5.1.1.

B.4.5.2.2 Is the particulate suspended in air? Yes. See B.4.5.1.2.

B.4.5.2.3 Is there sufficient concentration to propagate a flame front? Maybe. See B.4.5.1.3.

B.4.5.2.4 Are there competent igniters available? Yes. In addition to the igniters identified in B.4.5.1.4, a number of ignition mechanisms are introduced by the fan, including the following examples:

(1) Overheated drive bearings (especially the inboard bearing) due to bearing failure from lack of proper lubrication, fatigue, wear, etc.
(2) Fan impeller/wheel imbalance caused by material accumulation on the blades, bearing failure, wear, etc. (which can result in sparking by housing contact)

B.4.5.2.5 What hazard management is in place? *(See B.4.5.1.5.)* Other hazard management methods would include vibration monitoring (either by personnel on a regular basis or by a monitoring device), temperature monitoring of the drive bearings (by personnel or monitoring device) and amperage monitoring of the drive motor (generally, for a properly operating fan, amperage is directly related to the air mass flow — the higher the amperage, the more air mass flow).

B.4.5.3 Location 3: Duct from Fan to Cyclone.

B.4.5.3.1 Is the particulate deflagrable (explosible)? *(See B.4.5.1.1.)* However, the fan will cause particle attrition, increasing the relative concentration of fine particulate in the mixture. How much it is increased is not known unless a sieve analysis is conducted comparing material before and after the fan.

B.4.5.3.2 Is the particulate suspended in air? Yes. *(See B.4.5.1.2.)*

B.4.5.3.3 Is there sufficient concentration to propagate a flame front? Maybe. *(See B.4.5.1.3, but with the caveat that fan-produced particle attrition will increase the fines content.)*

B.4.5.3.4 Are there competent igniters available? Yes. In addition to those from the infeed 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 they get to locations where they could serve as ignition sources for a dust deflagration.

B.4.5.3.5 What hazard management is in place? Is there spark detection and extinguishment? Is there metal detection?

B.4.5.4 Location 4: Cyclone. Cyclones are designed to use particulate inertia to separate the particulate from the conveyance air. Deflagrations can occur in cyclones. Cyclones intentionally concentrate particulate near the perimeter of the cyclone. Cyclones also cause the large particles to separate from the fine material. Both of these factors increase the likelihood that a portion of the volume within the cyclone will have conditions sufficient for a deflagration. *(See Figure B.4.5.4.)*

B.4.5.4.1 Is the particulate deflagrable (explosible)? If there are any fines in the process particulate they will be separated, at least partially, from the larger particulates and concentrated by the cyclone. Because the fan creates fines and there is particle attrition as particulate goes rattling up the duct, the likely conclusion is yes.

B.4.5.4.2 Is the particulate suspended in air? Yes.

B.4.5.4.3 Is there sufficient concentration to propagate a flame front? Probably, and that translates to a yes. This depends on the quantity of fine, deflagrable (explosible) particulate per unit of mass of total particulate moved and the volume of air to move it. Calculations should be performed to determine if there is sufficient fine material per unit of air volume under the range of operating conditions to achieve a concentration of deflagrable particulate in excess of the MEC and render the cyclone an explosion hazard.

B.4.5.4.4 Are there competent igniters available? Yes. All of the ignition sources identified in the earlier portions of the system will be sending the ignited particulate to the cyclone.

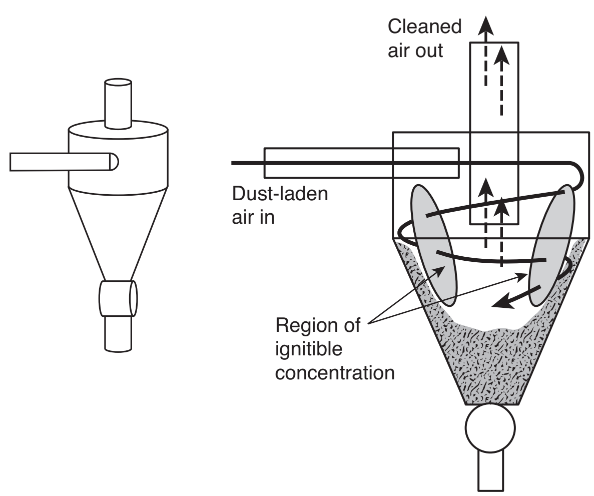


FIGURE B.4.5.4 The Operating Cyclone in Cross-Section. *(Source: J. M. Cholin Consultants, Inc.)*

Therefore, there is no alternative but to consider the cyclone an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.4.5 What hazard management is in place? The cyclone should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device.

If the system is shut down and there is burning material in the hopper section (base) of the cyclone, how is that managed? Most explosions result from deflagrations that are initiated by ongoing fires. Is there any fire detection in place? What is the plan if a fire is detected? (Dumping burning material into a silo is not an option.)

B.4.5.5 Location 5: Storage Silo. Every storage vessel is a particle size separator. When a mixture of material is dumped into a silo, bin, bunker, and so forth, the large particulate falls rapidly to the bottom of the vessel while the fines are lifted up by the air being displaced by the large particulate. This creates a cloud of fine dust in the ullage space, above the settled material. If any burning material or matter at a temperature above the auto-ignition temperature of the fine dust passes through this cloud, a deflagration is likely to result. *(See Figure B.4.5.5.)*

B.4.5.5.1 Is the particulate deflagrable (explosible)? Yes. The fines have separated from the coarse material and are suspended in a cloud in the ullage space.

B.4.5.5.2 Is the particulate suspended in air? Yes. The large particulate falls faster than the fines due to its lower Reynolds Number. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo, the greater the concentration of dust in that cloud.

B.4.5.5.3 Is there sufficient concentration to propagate a flame front? Eventually, yes. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo, the greater the concentration of dust in that cloud.

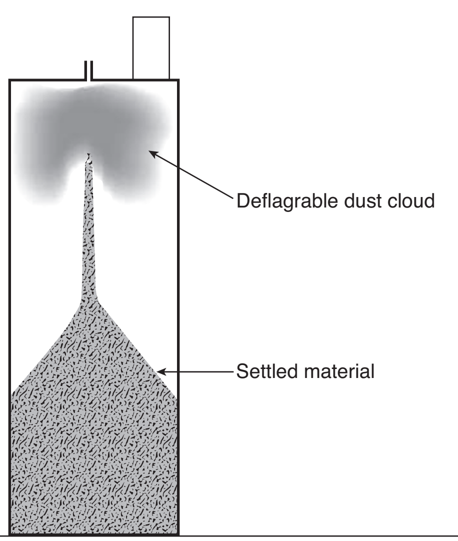


FIGURE B.4.5.5 A Silo Serves as a Particle Size Separator and Becomes an Explosion Hazard. *(Courtesy: J.M.Cholin Consultants, Inc.)*

B.4.5.5.4 Are there competent igniters available? Yes. All the ignition sources identified in the earlier portions of the system send the ignited particulate through the cyclone and on to the silo. The rotary air lock at the base of the cyclone hopper section can also be an ignition source in some cases where tramp metal has been introduced in the process stream. Therefore, there is no alternative but to consider the silo an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.5.5 What hazard management is in place? The silo should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device. It is also likely that the mass of material in the bottom of the silo will serve as isolation.

B.4.5.6 Location 7: The Outfeed Screw Conveyor.

B.4.5.6.1 Is the particulate deflagrable (explosible)? The material moving through this conveyor is a mixture of the large chips and the fine dust that eventually settled from the ullage space. So, there is a deflagrable (explosible) fraction included in the coarse material. The question is whether that fine fraction can become suspended.

B.4.5.6.2 Is the particulate suspended in air? It depends on the screw conveyor. Usually materials only fill the bottom half of a screw conveyor. There are exceptions. If the screw conveyor is rotating slowly, the rotation of the flight does not lift the fine material and put it into air suspension in the upper half of the conveyor interior. If the screw conveyor is operating at a high speed, then the rotation of the flight will suspend material above the central axis of the screw and produce a dust suspension within the screw conveyor. We have to assume this is the case unless we can prove otherwise. Generally, edge of the conveyor flight will attain speeds of 16.5 ft/sec (5 m/sec) to achieve a sustained dust cloud. (This number is half the minimum air entrainment value reported for glass microspheres in Ural, "Towards Estimating Entrainment Fraction for Dust Layers." See also NFPA 68.)

B.4.5.6.3 Is there sufficient concentration to support a deflagration? The fine dust is remixed with the coarse material so the concentration is a function of the percentage of the material that is the fine fraction and the air volume in the screw conveyor. If this concentration can exceed 25 percent of the MEC, then one can assume that there is sufficient concentration to propagate a deflagration.

B.4.5.6.4 Are there competent igniters available? Yes. It is quite possible that burning material was loaded into the silo; wood particulates are notorious for sustaining a smoldering combustion process for extended periods of time. Furthermore, the screw conveyor has bearings. Many screw conveyors have hanger bearings that are in the material stream and are potential ignition sources.

Consequently, it is very likely that if the speed of the screw is sufficient, the screw conveyor will be designated as a deflagration hazard and explosion management provisions will be necessary.

B.4.5.6.5 What hazard management is in place? Deflagration suppression and isolation is generally needed on high-speed screws. However, it might be possible to manage the hazard by replacing the screw with one that has a larger diameter but operates too slowly to produce a dust suspension. Sometimes changing the process or process equipment can reduce or eliminate the hazard, and that might be the best strategy.

B.4.5.7 Location 8: The Mill and Discharge Fan. Most mills in this kind of process require air flow through the mill as part of the milling process. This is typically provided by a fan package (positive or negative pressure, depending upon type of system), which can be integral to the mill or a separate device.

Δ **B.4.5.7.1** Is the particulate deflagrable (explosible)? It depends. What is the target product particle size? If the mill has ¼ in. (6.35 mm) screens, then the unit is receiving large particles and making them less large, but they're still too large to be considered a deflagrable (explosible) particulate. If the mill is reducing the particulate down to a fine powder, then the particulate would probably be considered deflagrable (explosible). Determination of whether the particulate in the mill is typically deflagrable is based on the range of particle size exiting the mill. It is usually necessary to submit this material for a go/no-go screening test to determine if the mixture exiting the mill is capable of propagating a deflagration flame front. However, there is a potential that the concentration of fines inside the mill might be higher than the concentration in the product stream due to recirculation within the mill.

B.4.5.7.2 Is the particulate suspended in air? Yes. Inside the mill and its associated fan, the particulate is in continuous air suspension.

B.4.5.7.3 Is there sufficient concentration to support deflagration? Because most mills produce fines during the milling process (due to remilling, turbulence, accumulations on internal surfaces, wear, etc.) and it is difficult to be assured that the fines concentrations do not exceed the MEC, it is best to assume sufficient combustible dusts are present. However, some low-speed mills (e.g., shredders) designed to produce only large particles might allow a determination from a sieve analysis and/or testing. Remember that while a sieve analysis is not a definitive criterion for identifying whether a particulate is deflagrable (explosible), it is a very valuable tool for identifying changes that have occurred in the process that signify a change in the hazard associated with the particulate. It is a management of change and safety assessment audit tool.

B.4.5.7.4 Are there competent igniters available? Most mills are capable of igniting the material being milled. If tramp metal gets into the process stream,there is a potential for ignition. Integral or external fan packages also represent additional hazards similar to the fan described in B.4.5.2.4.

B.4.5.7.5 What hazard management is in place? Are there magnetic separators or traps on the infeed to the mill? Is there deflagration suppression and isolation on the mill? Even if the mill is designed to be strong enough to withstand a deflagration within (many are), the deflagration flame front will exit the mill via the infeed and outfeed. What provisions are in place to isolate the mill from the rest of the process? In addition, any integral or external (in-line) fan package would require management such as that discussed in B.4.5.2.5.

B.4.5.8 Location 9: The Mill Discharge Duct to Screens.

B.4.5.8.1 Is the particulate deflagrable (explosible)? *(See B.4.5.7.1.)* If the material is deflagrable this duct can pose a significant hazard.

B.4.5.8.2 Is the particulate suspended in air? Yes. It is a pneumatic conveying duct — but what kind? If it is a dilute-phase conveying duct, then the material is suspended in air and the level of concentration becomes an important issue. However, if the plant is designed with a dense-phase or semi-dense-phase conveying system at this location, then the material does not move as an air suspension but as a region of concentrated material that usually does not represent a deflagration hazard in the duct under normal operating conditions.

B.4.5.8.3 Is there sufficient concentration to support a deflagration? If the duct is part of a dilute phase conveying setup, then the duct must be considered a deflagration hazard if the concentration exceeds 25 percent of the MEC for the material in the duct. If the material is tested and it does not propagate a deflagration flame front, then concentration ceases to be an issue. But if the material in the duct can propagate a deflagration flame front, then the concentration must be limited by the system design, or deflagration hazard management must be applied to the duct.

B.4.5.8.4 Are there competent igniters available? Yes. This duct is immediately downstream from the mill or fan package, either of which can be a source of ignition.

B.4.5.8.5 What hazard management is in place? If the particulate is sufficiently small enough to produce an affirmative test for deflagration flame front propagation, then the entire duct represents an explosion hazard, and that hazard must be managed. If it does not, either because the particulate is not deflagrable or dense-phase conveying is being used, then it does not. The analysis should document whether the duct is a deflagration hazard and if it is, how that hazard is being managed.

B.4.5.9 Location 10: The Screens.

B.4.5.9.1 Is the particulate deflagrable (explosible)? This is the same particulate that is exiting the mill, so that analysis is applicable to the screens.

B.4.5.9.2 Is the particulate suspended in air? This depends on the type, make, and model of the screens used. Some agitate the material more aggressively than others. An analysis of the operating screens for the presence of a dust suspension should be undertaken to determine if this criterion is satisfied.

Without proper dust collection, these devices can emit combustible dusts into the surrounding area.

B.4.5.9.3 Is there sufficient concentration to support deflagration? This criterion is again determined by the fraction of the process particulate that is sufficiently small to propagate a dust deflagration flame front. Note that the screens are equipped with dust collection. What is the air flow rate for the dust collection? What is the fraction of the particulate that is sufficiently small to propagate a deflagration flame front? How much of that dust is captured by the dust collection system? There are cases where a deflagration hazard has been successfully managed by just keeping the concentration below the 25 percent MEC threshold with active dust collection.

B.4.5.9.4 Are there competent igniters available? This depends on the type of screens used. Usually the bearings and moving members are located outside of the material flow path. However, there are ignition sources upstream in the process that could be a source of burning material introduced onto the screens. Usually this poses a fire hazard rather a deflagration hazard. But that fire hazard must be managed.

B.4.5.9.5 What hazard management is in place? Depending on whether the screens are found to be a deflagration hazard or a fire hazard, different hazard management strategies will apply. The strategy employed and the reason for selecting that strategy should be documented.

B.4.5.10 This example includes other ducts, conveyors, and other process equipment that would be addressed in a manner similar to those already covered. However, there are two hazards that have not yet been addressed: the building compartment and the dust collector.

B.4.5.11 Location 2: The Building Compartment Housing the Process.

B.4.5.11.1 Is the particulate deflagrable (explosible)? There are a number of pieces of equipment that can leak dust. The leaks always constitute the fines fraction of the particulate being handled. In addition, air movement generally lifts the finest, most hazardous dust highest in the space. So the hazard assessment for the building compartment is based on the test data for the fine dust that is obtained from the highest locations in the building compartment.

Is there sufficient fugitive dust accumulation within the building to trigger the designation of deflagration hazard or flash-fire hazard in the building interior?

If the building compartment contains sufficient fugitive dust accumulations to warrant designating it a deflagration of flash-fire hazard, then the occupant must be protected from the building interior. This requires the use of flame-resistant garments and a housekeeping program. Venting is one common approach to protect against building collapse.

Furthermore, dust accumulations trigger requirements for using electrical equipment that is listed as suitable for Class II hazardous locations in accordance with Articles 500 through 506 of *NFPA 70.*

B.4.5.11.2 Is the particulate suspended in air? Most large-loss explosions involving combustible dust have occurred because a small event produced an ignition mechanism and a dust dispersion of the accumulated fugitive dust in the building interior.

B.4.5.11.3 Is there sufficient concentration to support a deflagration? Generally, the dust layer criteria in the occupancy standards are derived from calculations that take into consideration the requisite concentrations to propagate a flame front.

B.4.5.11.4 Are there competent igniters available? Under abnormal (accident) conditions the answer is usually yes.

B.4.5.11.5 What hazard management is in place? Deflagration venting for compartments is a common management strategy to preserve the building integrity. What provisions are in place to protect the employees from a propagating deflagration (flash fire)? Is the housekeeping program sufficient to prevent fugitive dust layer from developing over time?

B.4.5.12 The Dust Collector. The dust collector in this example is located outside of the building, but it is equipped with a clean air return to the facility interior. This triggers the need to protect the employees within the facility compartment from a fire in the dust collector as well as a deflagration in the dust collector.

B.4.5.12.1 Is the particulate deflagrable (explosible)? Probably. This dust collector is collecting the fines that are generated by various process steps including the dust suspended in the silo ullage space, the silo discharge screw conveyor, the screens, and the product out-feed screw.

B.4.5.12.2 Is the particulate suspended in air? Yes. Dust collection systems are invariably designed as dilute phase conveying systems.

B.4.5.12.3 Is there sufficient concentration to support deflagration? Usually such dust collection systems operate at dust loadings in the ducts in the range of 1 to 3 g/m^3; well below the 25 percent MEC range for most dusts. But this parameter must be verified and documented. So the ducts are probably not a deflagration hazard, but the dust collector's job is to concentrate that dust. So an ignitable concentration of dust within the dust collector is probably certain.

B.4.5.12.4 Are there competent igniters available? Generally, yes. All of the ignition sources in the entire process have access to the dust collector via the dust collection ducts. While the concentration in those ducts is typically well below the MEC, there is always the potential for a burning particle to survive the trip from the point of ignition to the dust collector interior, where it can become attached to the filter media and ignite a fire. For many particulates there is an electrostatic ignition mechanism present. For others, the inherent reactivity of the particulate with atmospheric oxygen makes them inherently self-igniting. All these sources of ignition have to be considered.

B.4.5.12.5 What hazard management is in place? The occupants must be protected from dust collector — fires as well as dust collector explosions. (In many industries dust collector fires outnumber dust collector explosions.) For dust collector fire, return air diversion to prevent combustion products from entering the building is sufficient. (Generally, dust collectors collecting metallic particulates are not permitted to return air to the building.) To protect occupants from the dust collector explosion, a common approach is to install deflagration isolation as well as either deflagration venting or deflagration suppression. The protection feature in place should be documented.

B.4.6 This example is intended to illustrate one process used in assessing the combustible dust hazards of a facility. Other methods are acceptable as long as they result in a thorough assessment of all the hazards in the process and facility and document how those hazards are managed. This example evaluated the following aspects of the process:

(1) Process equipment
(2) Process ductwork
(3) Facilities compartments

Individual hazards for these three areas would be considered in the aggregate to determine the overall hazards of the process.

 Shaded text = Revisions. Δ = Text deletions and figure/table revisions. • = Section deletions. *N* = New material.

Annex C Accumulated Fugitive Dust

This annex is not a part of the requirements of this NFPA document but is included for informational purposes only.

C.1 Accumulated Fugitive Dust. As noted elsewhere in the standard, there are two considerations for assessing accumulated fugitive dust hazards — one that indicates that a dust flash-fire or dust explosion hazard exists and the other that indicates where protected electrical equipment might be needed. Figure C.1 is a representation of provisions defined in Articles 500–505 of *NFPA 70* to assist in determining where hazardous (classified) locations can exist.

Other factors associated with accumulated fugitive dust include the following:

(1) Accumulated fugitive dust is the single most important factor in propagating a deflagration within a building.
(2) Dust layers trigger critical hazard management decisions.

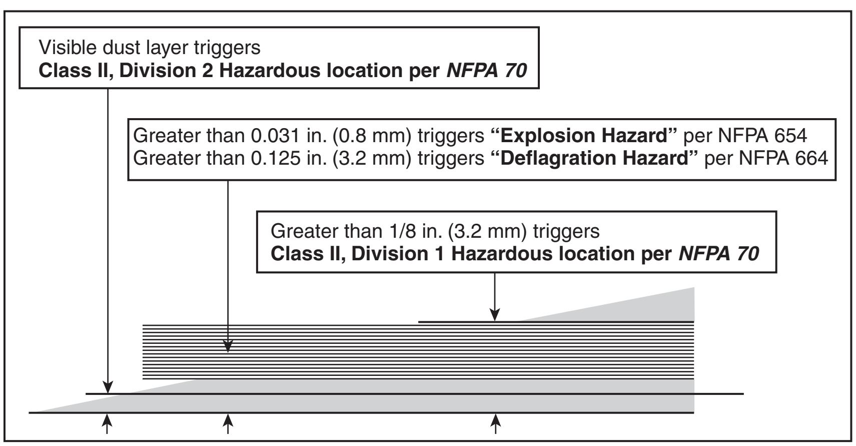
C.2 Electrical Equipment for Hazardous Occupancies. All electrical equipment must be listed for use in the occupancy based on the class, division, and group classification. When all electrical equipment in the occupancy is listed for use in that occupancy, the electrical system is deemed to not be a likely igniter. The extent of the electrically classified area is controlled by the rate of dust release and the frequency of clean-up.

C.3 Building Compartments. Where management of the hazard is dependent on routine cleaning, that cleaning program should be outlined in the DHA.

Δ **C.4 Explosion Hazards.** Dust explosion hazards exist wherever combustible particulate solids are handled or produced. There is no alternative to proactively managing the hazard, and the following questions should be considered when assessing the risk:

(1) Is there accumulated fugitive dust? If so, how much is there and where is it?
(2) What is the MEC, MIE, and K_{St} of the particulate in the dust?
(3) Does the building compartment pose a deflagration hazard?
(4) Does the building compartment pose an explosion hazard?
(5) Does the building compartment pose a fire hazard?

Most instances of property damage and personnel injury are due to fugitive dust accumulations within building compartments. *Control, limitation, or elimination of accumulated fugitive dust are critical and the most important criteria for a safe workplace.*



Δ **FIGURE C.1 Comparison of Accumulated Fugitive Dust Thicknesses.** ***(Source: J. M. Cholin Consultants, Inc.)***

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 30B, *Code for the Manufacture and Storage of Aerosol Products*, 2019 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, 2018 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2019 edition.

NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities,* 2017 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2018 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2014 edition.

NFPA 70®, *National Electrical Code®*, 2017 edition.

NFPA 70B, *Recommended Practice for Electrical Equipment Maintenance,* 2016 edition.

NFPA 70E®, *Standard for Electrical Safety in the Workplace®*, 2018 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2019 edition.

NFPA 85, *Boiler and Combustion Systems Hazard Code*, 2015 edition.

NFPA *101®*, *Life Safety Code®*, 2018 edition.

NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*, 2015 edition.

NFPA 220, *Standard on Types of Building Construction*, 2018 edition.

NFPA 484, *Standard for Combustible Metals*, 2019 edition.

NFPA 495, *Explosive Materials Code*, 2018 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2017 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2017 edition.

NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*, 2017 edition.

NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*, 2017 edition.

NFPA 820, *Standard for Fire Protection in Wastewater Treatment and Collection Facilities*, 2016 edition.

NFPA 850, *Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations*, 2015 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High Power Rocket Motors*, 2017 edition.

NFPA 2112, *Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire*, 2018 edition.

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*, 2015 edition.

NFPA *Fire Protection Handbook*, 2008 edition.

NFPA *Guide to Combustible Dusts*, 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.

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Sequence of Events for the Standards Development Process

Once the current edition is published, a Standard is opened for Public Input.

Step 1 – Input Stage

- Input accepted from the public or other committees for consideration to develop the First Draft
- Technical Committee holds First Draft Meeting to revise Standard (23 weeks); Technical Committee(s) with Correlating Committee (10 weeks)
- Technical Committee ballots on First Draft (12 weeks); Technical Committee(s) with Correlating Committee (11 weeks)
- Correlating Committee First Draft Meeting (9 weeks)
- Correlating Committee ballots on First Draft (5 weeks)
- First Draft Report posted on the document information page

Step 2 – Comment Stage

- Public Comments accepted on First Draft (10 weeks) following posting of First Draft Report
- If Standard does not receive Public Comments and the Technical Committee chooses not to hold a Second Draft meeting, the Standard becomes a Consent Standard and is sent directly to the Standards Council for issuance (see Step 4) or
- Technical Committee holds Second Draft Meeting (21 weeks); Technical Committee(s) with Correlating Committee (7 weeks)
- Technical Committee ballots on Second Draft (11 weeks); Technical Committee(s) with Correlating Committee (10 weeks)
- Correlating Committee Second Draft Meeting (9 weeks)
- Correlating Committee ballots on Second Draft (8 weeks)
- Second Draft Report posted on the document information page

Step 3 – NFPA Technical Meeting

- Notice of Intent to Make a Motion (NITMAM) accepted (5 weeks) following the posting of Second Draft Report
- NITMAMs are reviewed and valid motions are certified by the Motions Committee for presentation at the NFPA Technical Meeting
- NFPA membership meets each June at the NFPA Technical Meeting to act on Standards with "Certified Amending Motions" (certified NITMAMs)
- Committee(s) vote on any successful amendments to the Technical Committee Reports made by the NFPA membership at the NFPA Technical Meeting

Step 4 – Council Appeals and Issuance of Standard

- Notification of intent to file an appeal to the Standards Council on Technical Meeting action must be filed within 20 days of the NFPA Technical Meeting
- Standards Council decides, based on all evidence, whether to issue the standard or to take other action

Notes:

1. Time periods are approximate; refer to published schedules for actual dates.
2. Annual revision cycle documents with certified amending motions take approximately 101 weeks to complete.
3. Fall revision cycle documents receiving certified amending motions take approximately 141 weeks to complete.

Committee Membership Classifications[1,2,3,4]

The following classifications apply to Committee members and represent their principal interest in the activity of the Committee.

1. M *Manufacturer:* A representative of a maker or marketer of a product, assembly, or system, or portion thereof, that is affected by the standard.
2. U *User:* A representative of an entity that is subject to the provisions of the standard or that voluntarily uses the standard.
3. IM *Installer/Maintainer:* A representative of an entity that is in the business of installing or maintaining a product, assembly, or system affected by the standard.
4. L *Labor:* A labor representative or employee concerned with safety in the workplace.
5. RT *Applied Research/Testing Laboratory:* A representative of an independent testing laboratory or independent applied research organization that promulgates and/or enforces standards.
6. E *Enforcing Authority:* A representative of an agency or an organization that promulgates and/or enforces standards.
7. I *Insurance:* A representative of an insurance company, broker, agent, bureau, or inspection agency.
8. C *Consumer:* A person who is or represents the ultimate purchaser of a product, system, or service affected by the standard, but who is not included in (2).
9. SE *Special Expert:* A person not representing (1) through (8) and who has special expertise in the scope of the standard or portion thereof.

NOTE 1: "Standard" connotes code, standard, recommended practice, or guide.

NOTE 2: A representative includes an employee.

NOTE 3: While these classifications will be used by the Standards Council to achieve a balance for Technical Committees, the Standards Council may determine that new classifications of member or unique interests need representation in order to foster the best possible Committee deliberations on any project. In this connection, the Standards Council may make such appointments as it deems appropriate in the public interest, such as the classification of "Utilities" in the National Electrical Code Committee.

NOTE 4: Representatives of subsidiaries of any group are generally considered to have the same classification as the parent organization.

Submitting Public Input / Public Comment Through the Online Submission System

Soon after the current edition is published, a Standard is open for Public Input.

Before accessing the Online Submission System, you must first sign in at www.nfpa.org. *Note: You will be asked to sign-in or create a free online account with NFPA before using this system:*

a. Click on Sign In at the upper right side of the page.
b. Under the Codes and Standards heading, click on the "List of NFPA Codes & Standards," and then select your document from the list or use one of the search features.

OR

a. Go directly to your specific document information page by typing the convenient shortcut link of www.nfpa.org/document# (Example: NFPA 921 would be www.nfpa.org/921). Sign in at the upper right side of the page.

To begin your Public Input, select the link "The next edition of this standard is now open for Public Input" located on the About tab, Current & Prior Editions tab, and the Next Edition tab. Alternatively, the Next Edition tab includes a link to Submit Public Input online.

At this point, the NFPA Standards Development Site will open showing details for the document you have selected. This "Document Home" page site includes an explanatory introduction, information on the current document phase and closing date, a left-hand navigation panel that includes useful links, a document Table of Contents, and icons at the top you can click for Help when using the site. The Help icons and navigation panel will be visible except when you are actually in the process of creating a Public Input.

Once the First Draft Report becomes available there is a Public Comment period during which anyone may submit a Public Comment on the First Draft. Any objections or further related changes to the content of the First Draft must be submitted at the Comment stage.

To submit a Public Comment you may access the online submission system utilizing the same steps as previously explained for the submission of Public Input.

For further information on submitting public input and public comments, go to: http://www.nfpa.org/publicinput.

Other Resources Available on the Document Information Pages

About tab: View general document and subject-related information.

Current & Prior Editions tab: Research current and previous edition information on a Standard.

Next Edition tab: Follow the committee's progress in the processing of a Standard in its next revision cycle.

Technical Committee tab: View current committee member rosters or apply to a committee.

Technical Questions tab: For members and Public Sector Officials/AHJs to submit questions about codes and standards to NFPA staff. Our Technical Questions Service provides a convenient way to receive timely and consistent technical assistance when you need to know more about NFPA codes and standards relevant to your work. Responses are provided by NFPA staff on an informal basis.

Products & Training tab: List of NFPA's publications and training available for purchase.

Information on the NFPA Standards Development Process

I. Applicable Regulations. The primary rules governing the processing of NFPA standards (codes, standards, recommended practices, and guides) are the NFPA *Regulations Governing the Development of NFPA Standards (Regs)*. Other applicable rules include NFPA *Bylaws*, NFPA *Technical Meeting Convention Rules*, NFPA *Guide for the Conduct of Participants in the NFPA Standards Development Process*, and the NFPA *Regulations Governing Petitions to the Board of Directors from Decisions of the Standards Council*. Most of these rules and regulations are contained in the *NFPA Standards Directory*. For copies of the *Directory*, contact Codes and Standards Administration at NFPA Headquarters; all these documents are also available on the NFPA website at "www.nfpa.org."

The following is general information on the NFPA process. All participants, however, should refer to the actual rules and regulations for a full understanding of this process and for the criteria that govern participation.

II. Technical Committee Report. The Technical Committee Report is defined as "the Report of the responsible Committee(s), in accordance with the Regulations, in preparation of a new or revised NFPA Standard." The Technical Committee Report is in two parts and consists of the First Draft Report and the Second Draft Report. (See *Regs* at Section 1.4.)

III. Step 1: First Draft Report. The First Draft Report is defined as "Part one of the Technical Committee Report, which documents the Input Stage." The First Draft Report consists of the First Draft, Public Input, Committee Input, Committee and Correlating Committee Statements, Correlating Notes, and Ballot Statements. (See *Regs* at 4.2.5.2 and Section 4.3.) Any objection to an action in the First Draft Report must be raised through the filing of an appropriate Comment for consideration in the Second Draft Report or the objection will be considered resolved. [See *Regs* at 4.3.1(b).]

IV. Step 2: Second Draft Report. The Second Draft Report is defined as "Part two of the Technical Committee Report, which documents the Comment Stage." The Second Draft Report consists of the Second Draft, Public Comments with corresponding Committee Actions and Committee Statements, Correlating Notes and their respective Committee Statements, Committee Comments, Correlating Revisions, and Ballot Statements. (See *Regs* at 4.2.5.2 and Section 4.4.) The First Draft Report and the Second Draft Report together constitute the Technical Committee Report. Any outstanding objection following the Second Draft Report must be raised through an appropriate Amending Motion at the NFPA Technical Meeting or the objection will be considered resolved. [See *Regs* at 4.4.1(b).]

V. Step 3a: Action at NFPA Technical Meeting. Following the publication of the Second Draft Report, there is a period during which those wishing to make proper Amending Motions on the Technical Committee Reports must signal their intention by submitting a Notice of Intent to Make a Motion (NITMAM). (See *Regs* at 4.5.2.) Standards that receive notice of proper Amending Motions (Certified Amending Motions) will be presented for action at the annual June NFPA Technical Meeting. At the meeting, the NFPA membership can consider and act on these Certified Amending Motions as well as Follow-up Amending Motions, that is, motions that become necessary as a result of a previous successful Amending Motion. (See 4.5.3.2 through 4.5.3.6 and Table 1, Columns 1-3 of *Regs* for a summary of the available Amending Motions and who may make them.) Any outstanding objection following action at an NFPA Technical Meeting (and any further Technical Committee consideration following successful Amending Motions, see *Regs* at 4.5.3.7 through 4.6.5.3) must be raised through an appeal to the Standards Council or it will be considered to be resolved.

VI. Step 3b: Documents Forwarded Directly to the Council. Where no NITMAM is received and certified in accordance with the Technical Meeting Convention Rules, the standard is forwarded directly to the Standards Council for action on issuance. Objections are deemed to be resolved for these documents. (See *Regs* at 4.5.2.5.)

VII. Step 4a: Council Appeals. Anyone can appeal to the Standards Council concerning procedural or substantive matters related to the development, content, or issuance of any document of the NFPA or on matters within the purview of the authority of the Council, as established by the Bylaws and as determined by the Board of Directors. Such appeals must be in written form and filed with the Secretary of the Standards Council (see *Regs* at Section 1.6). Time constraints for filing an appeal must be in accordance with 1.6.2 of the *Regs*. Objections are deemed to be resolved if not pursued at this level.

VIII. Step 4b: Document Issuance. The Standards Council is the issuer of all documents (see Article 8 of *Bylaws*). The Council acts on the issuance of a document presented for action at an NFPA Technical Meeting within 75 days from the date of the recommendation from the NFPA Technical Meeting, unless this period is extended by the Council (see *Regs* at 4.7.2). For documents forwarded directly to the Standards Council, the Council acts on the issuance of the document at its next scheduled meeting, or at such other meeting as the Council may determine (see *Regs* at 4.5.2.5 and 4.7.4).

IX. Petitions to the Board of Directors. The Standards Council has been delegated the responsibility for the administration of the codes and standards development process and the issuance of documents. However, where extraordinary circumstances requiring the intervention of the Board of Directors exist, the Board of Directors may take any action necessary to fulfill its obligations to preserve the integrity of the codes and standards development process and to protect the interests of the NFPA. The rules for petitioning the Board of Directors can be found in the *Regulations Governing Petitions to the Board of Directors from Decisions of the Standards Council* and in Section 1.7 of the *Regs*.

X. For More Information. The program for the NFPA Technical Meeting (as well as the NFPA website as information becomes available) should be consulted for the date on which each report scheduled for consideration at the meeting will be presented. To view the First Draft Report and Second Draft Report as well as information on NFPA rules and for up-to-date information on schedules and deadlines for processing NFPA documents, check the NFPA website (www.nfpa.org/docinfo) or contact NFPA Codes & Standards Administration at (617) 984-7246.