

NFPA[®] 660

Standard for Combustible Dusts and Particulate Solids

2025 Edition



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An International Codes and Standards Organization

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NFPA® 660

Standard for

Combustible Dusts and Particulate Solids

2025 Edition

This edition of NFPA 660, *Standard for Combustible Dusts and Particulate Solids*, was prepared by the Technical Committees on Fundamentals of Combustible Dusts, Agricultural Dusts, Combustible Metals and Metal Dusts, Handling and Conveying of Dusts, Vapors, and Gases, and Wood and Cellulosic Materials Processing, released by the Correlating Committee on Combustible Dusts. It was issued by the Standards Council on November 16, 2024, with an effective date of December 6, 2024.

This edition of NFPA 660 was approved as an American National Standard on December 6, 2024.

Origin and Development of NFPA 660

NFPA 660 was written by consolidating the requirements of NFPA 652, *Standard on the Fundamentals of Combustible Dust*; NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*; NFPA 484, *Standard for Combustible Metals*; NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*; NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities*; and NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, and making them into individual chapters in NFPA 660, so that this standard provides safety requirements for all combustible dusts and particulate solids.

One effect of this consolidation is that the definitions and terminology from each document have been standardized and are all found in Chapter 3, and fundamental requirements that apply to all of the industries or commodities covered by NFPA 660 are located in the first 10 chapters. Annex material in A.1.3 explains the organization of this combined document and how to determine the requirements for a piece of equipment, building, or facility.

The 2025 edition of NFPA 660 also includes some changes from the last editions of the source documents, including but not limited to the following:

- Requirements from the industry- or commodity-specific standards that were deemed to be fundamental have been moved to the first 10 chapters.
- Requirements that are covered in the fundamental chapters have been removed from the industry- and commodity-specific chapters.
- Terminology for “deflagration vent/venting” was made consistent throughout.
- Terminology for types of sulfur size reduction machinery was updated.
- Terms such as *transient releases*, *management of change*, *operational readiness review*, and *explosive- and propellant-actuated devices* have been defined.
- Requirements for operational readiness reviews have been added.
- New requirements have been added to evaluate self heating, thermal instability, water reactivity, and chemical reactivity hazards.
- Information has been added to document who is qualified to perform a DHA.
- Text has been added throughout Chapter 8 and the annexes to address the level of protection provided by flame-resistant garments.
- Elements of general safety training and job-specific training and frequency of refresher training have been specified.
- Requirements for bonding and grounding of housekeeping equipment have been clarified.
- Resistance limits for flexible connectors have been updated.
- References to risk assessments and DHAs have been edited for consistency throughout.
- Industrial hygiene exposure limits have been referenced for recycling of AMS exhaust to buildings.

- Changes in Chapter 21 clarify what kind of flexible connectors can be used in agricultural and food processing facilities.
- DHA requirements for existing processes and facility compartments in agricultural and food processing facilities have been revised.
- Guidance on responding to silo fires has been added.
- Test standards for portable vacuum cleaners used with combustible metals have been provided.
- Additive manufacturing requirements in Chapter 22 were updated.
- Changes in Chapters 23 and 25 clarify when manifolding of dust collection ducts is permitted.
- Guidance for spark detection systems has been updated.
- An annex has been added to assist in calculating the thermal dose to personnel from flash fires and building compartment deflagrations.

The technical committees would like to recognize two long-standing technical committee members, Erdem Ural and Robert Zalosh, who were instrumental in the development of several NFPA standards and passed away during the final stages of development of NFPA 660. Each having served more than 25 years on NFPA committees, they both had an incredible impact on the explosion protection and combustible dust industry, and their presence is deeply missed.

Finally, this edition of NFPA 660 is dedicated to workers who have suffered injuries or lost their lives from the hazards of combustible dusts, in the hope that it will help prevent such tragedies in the future.

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Committee Scope: This Committee shall have primary responsibility for documents on the prevention, control, and extinguishment of fire and explosions resulting from dusts produced by the processing, handling, and storage of grain, starch, food, animal feed, flour, and other agricultural products. The Technical Committee shall also be responsible for requirements relating to the protection of life and property from fire and explosion hazards at agricultural and food products facilities.

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Laura E. Moreno, NFPA Staff Liaison

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Technical Committee on Fundamentals of Combustible Dusts

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Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases

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Walter L. Frank, Frank Risk Solutions, Inc., PA [SE]
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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the prevention, control, and extinguishment of fires and explosions in the design, construction, installation, operation, and maintenance of facilities and systems processing or conveying flammable or combustible dusts, gases, vapors, and mists.

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NOTE: Membership on a committee shall not in and of itself constitute an endorsement of the Association or any document developed by the committee on which the member serves.

Committee Scope: This Committee shall have primary responsibility for documents on the prevention, control, and extinguishment of fires and explosions in wood processing, woodworking facilities, and facilities that use other cellulosic materials as a substitute or additive for wood.

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Standard for

Combustible Dusts and Particulate Solids

2025 Edition

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

A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1* Scope. This standard addresses the fire, flash fire, and explosion hazards of combustible dusts and particulate solids.

1.1.1 This standard also addresses agricultural and food processing facilities in accordance with the scope of Chapter 21.

1.1.2 This standard also addresses all metals and alloys that are in a form that is capable of combustion or explosion, as well as other hazards, in accordance with the scope of Chapter 22.

1.1.3 This standard also addresses the processing of sulfur and the handling of sulfur in any form, as well as other hazards entailed in processing sulfur, in accordance with the scope of Chapter 23.

1.1.4 This standard also addresses industrial, commercial, or institutional facilities that process wood or manufacture wood products using wood or other cellulosic fiber as a substitute for or an additive to wood fiber, and facilities that process wood, creating wood chips, particles, or dust, as well as other hazards

entailed in forest products facilities, in accordance with the scope of Chapter 24.

1.1.5 This standard also addresses processes and facilities handling combustible dusts and particulate solids not otherwise covered by Chapters 21, 22, 23, or 24, in accordance with the scope of Chapter 25.

1.2 Purpose. The purpose of this standard is to prescribe the minimum requirements necessary to prevent or mitigate the fire, flash fire, and explosion hazards posed by combustible dusts and particulate solids.

1.3* Application.

1.3.1 The owner/operator shall be responsible for implementing the requirements in this standard.

1.3.2* The user shall be permitted to use Figure 1.3.2 for guidance when using this standard.

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

1.3.4* This standard shall apply to the storage or use of ignitable fibers/flyings, specifically with regard to fire hazards.

1.3.5 This standard shall apply to the production, processing, handling, and storage of agricultural and food products as well as other hazards in accordance with the scope in Chapter 21.

1.3.6 This standard shall apply to the production, processing, finishing, handling, recycling, storage, and use of all metals and alloys that are in a form that is capable of combustion or explosion, as well as other hazards in accordance with the scope of Chapter 22.

1.3.7 This standard shall apply to the size reduction of sulfur and the handling of sulfur in any form, as well as other hazards entailed in processing sulfur, in accordance with the scope of Chapter 23.

1.3.8 This standard shall apply to industrial, commercial, or institutional facilities that process wood or manufacture wood products using wood or other cellulosic fiber as a substitute for or an additive to wood fiber, and facilities that process wood, creating wood chips, particles, or dust, as well as other hazards entailed in forest products facilities, in accordance with the scope of Chapter 24.

1.3.9 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, except where covered in Chapter 22
- (5) Such materials stored or used in farm buildings or similar occupancies for on-premises agricultural purposes

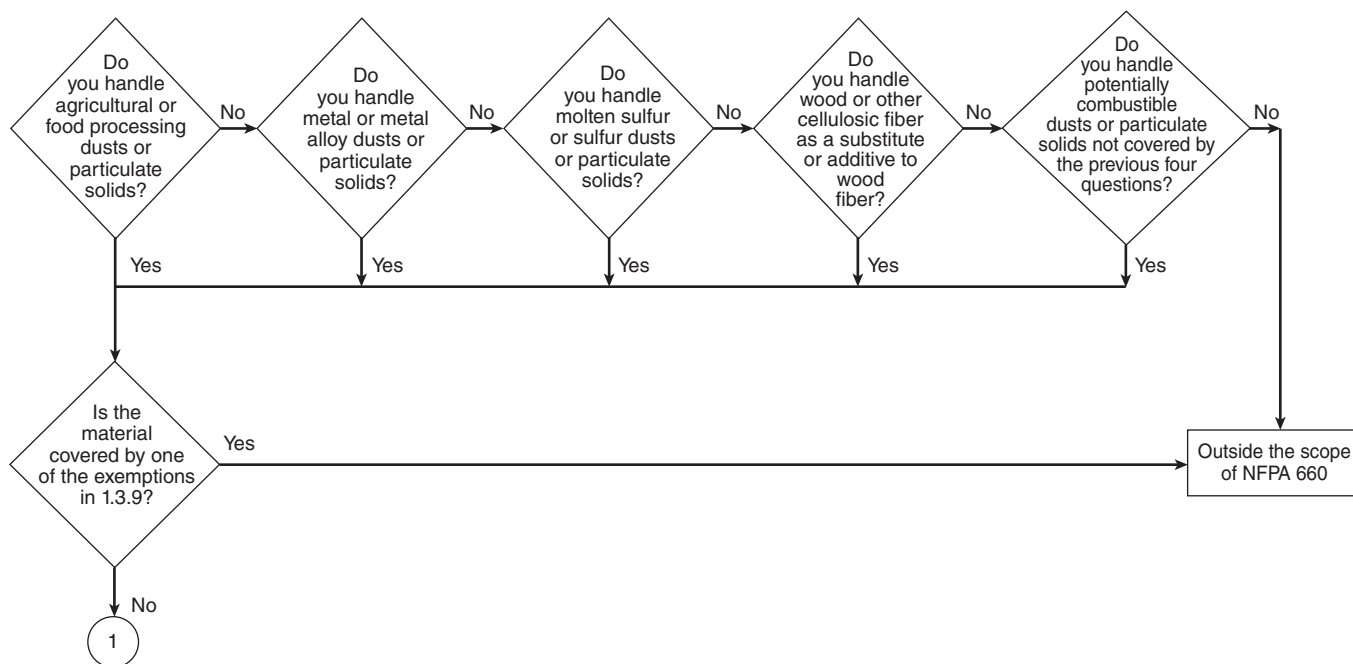


FIGURE 1.3.2 Document Flow Diagram for Combustible Dust Hazards Evaluation.

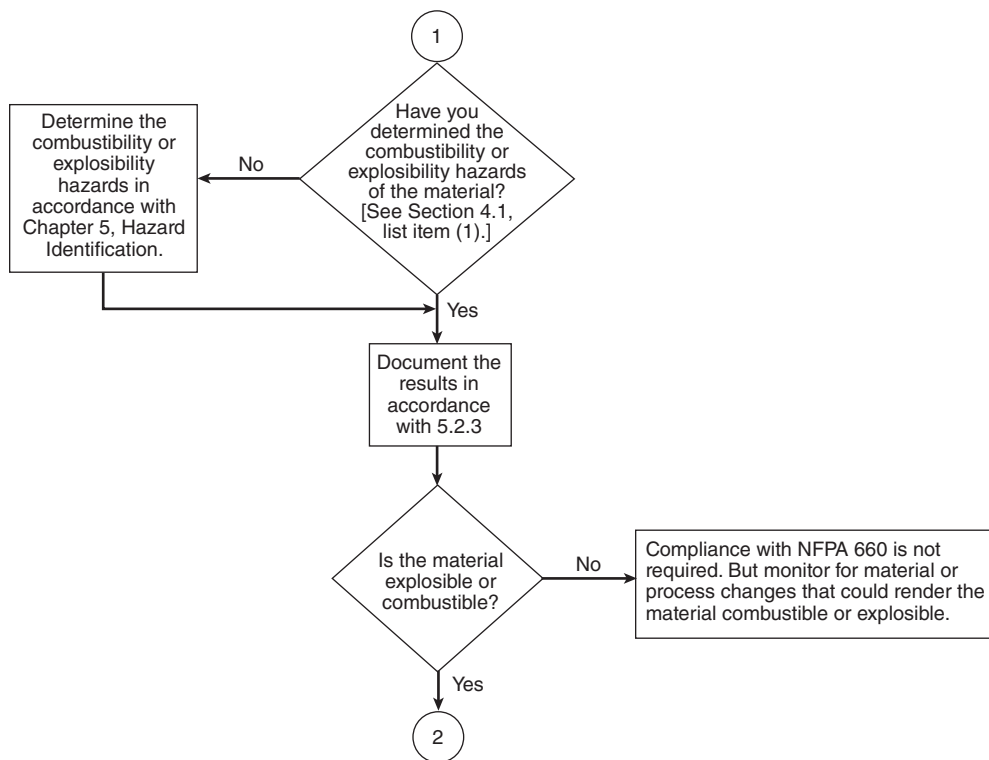


FIGURE 1.3.2 Continued

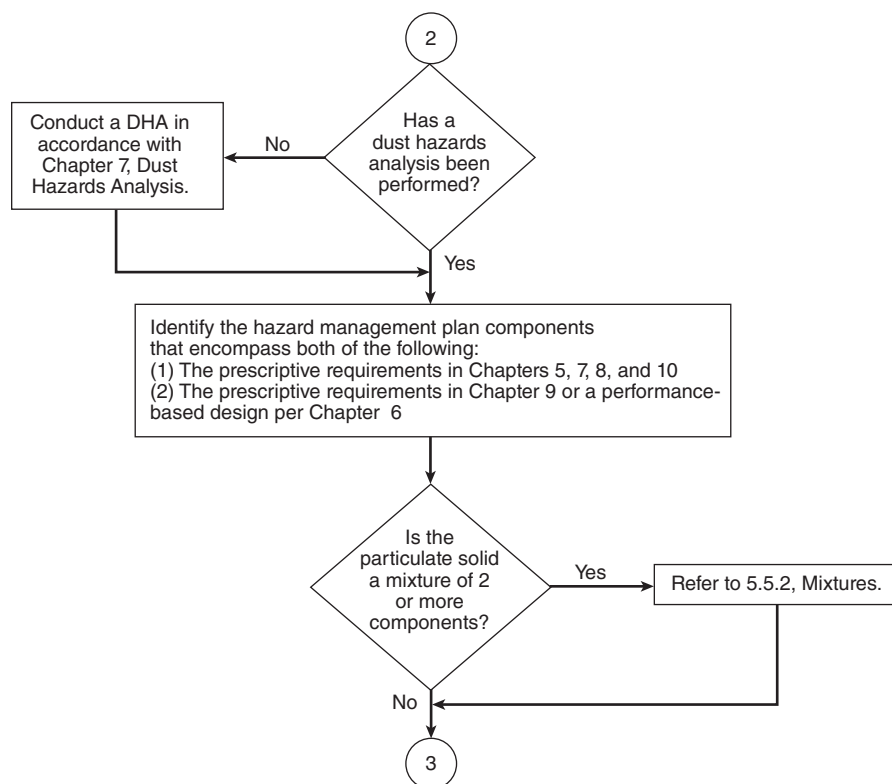


FIGURE 1.3.2 Continued

1.3.10 This standard shall not be required to apply to materials covered by the following documents, unless specifically referenced by the applicable document:

- (1) NFPA 30B
- (2) NFPA 33
- (3) NFPA 36
- (4) NFPA 85
- (5) NFPA 120
- (6) NFPA 400
- (7) NFPA 495
- (8) NFPA 1125

1.3.11 Where an industry- or commodity-specific chapter exists, the industry- or commodity-specific requirements of the appropriate chapter within this standard shall be applied in addition to the fundamental requirements specified in Chapters 1 through 10.

1.4* Retroactivity. 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.

1.4.1 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.

1.4.1.1 Where specified, the provisions of this standard shall be retroactive.

1.4.2* In those cases where the authority having jurisdiction determines that the existing situation presents an unacceptable degree of risk, the authority having jurisdiction shall be permitted to apply retroactively any portions of this standard 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.

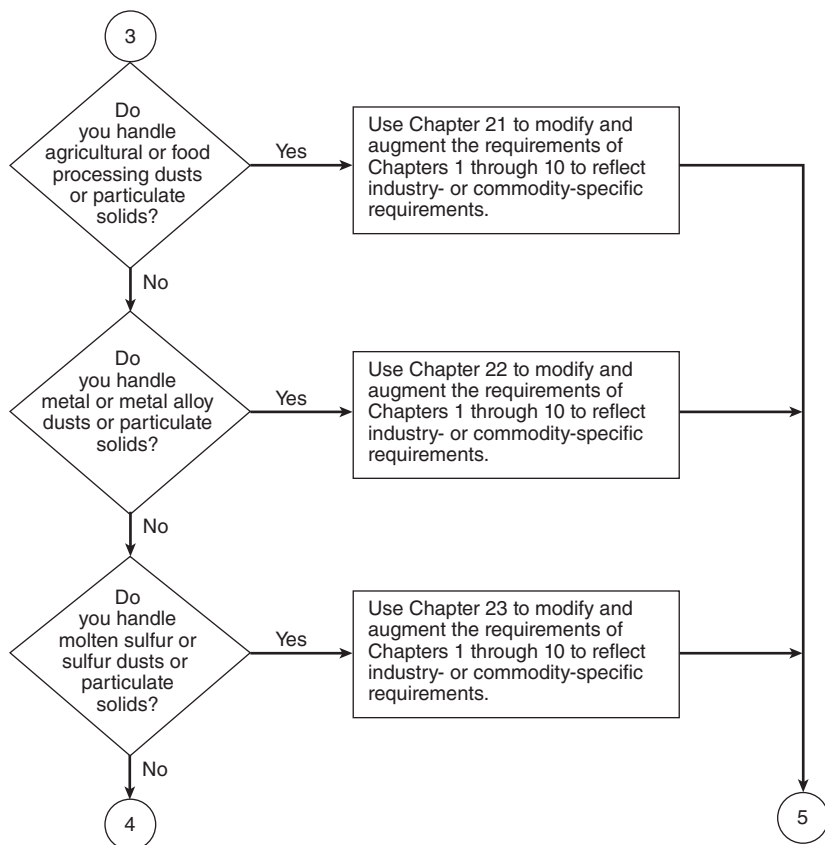
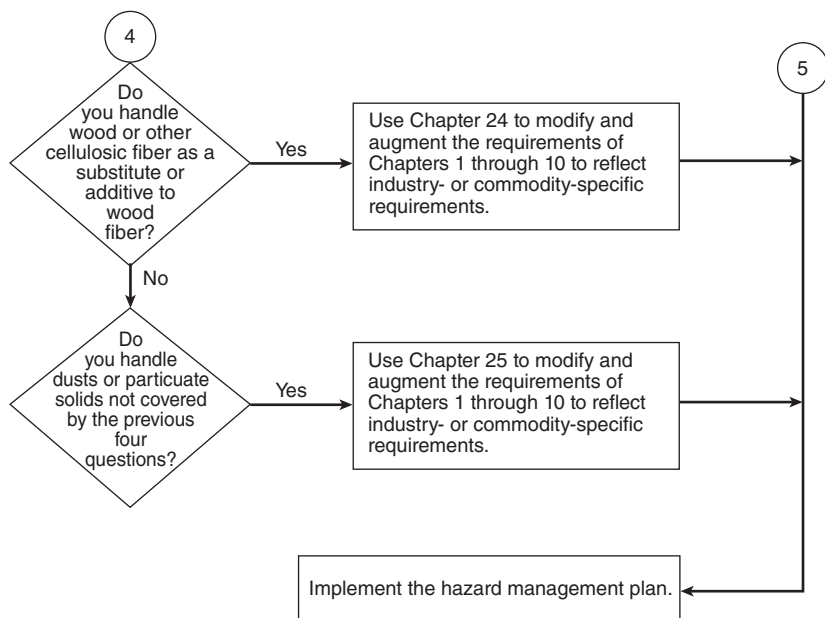
1.4.3 When modifying or adding to an existing facility, equipment, or process, the provisions of this standard shall apply to the affected portion of the facility, equipment, or process.

1.4.4 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.

1.5 Equivalency. 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.

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

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

FIGURE 1.3.2 *Continued*FIGURE 1.3.2 *Continued*

1.6 Conflicts.

1.6.1 For the purposes of this standard, the industry- or commodity-specific NFPA chapters shall include the following:

- (1) Chapter 21, Agricultural and Food Processing
- (2) Chapter 22, Combustible Metals
- (3) Chapter 23, Sulfur
- (4) Chapter 24, Wood Processing and Woodworking Facilities
- (5) Chapter 25, Combustible Dusts and Particulate Solids Not Otherwise Specified

1.6.2* Where a requirement in an industry- or commodity-specific chapter differs from the requirement specified as a fundamental requirement in Chapters 1 through 10, the requirement in the industry- or commodity-specific chapter shall be permitted to be used.

1.6.3 Where an industry- or commodity-specific chapter specifically prohibits a fundamental requirement specified in Chapters 1 through 10, the prohibition in the industry- or commodity-specific chapter shall be applied.

1.6.4 Where an industry- or commodity-specific chapter neither prohibits nor provides a requirement or says *Reserved*, the fundamental requirements in Chapters 1 through 10 shall be applied.

1.6.5 An industry- or commodity-specific chapter shall be permitted to establish requirements on subjects not specified in Chapters 1 through 10.

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 1, *Fire Code*, 2024 edition.
- NFPA 2, *Hydrogen Technologies Code*, 2023 edition.
- NFPA 10, *Standard for Portable Fire Extinguishers*, 2022 edition.
- NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam*, 2024 edition.
- NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems*, 2025 edition.
- NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems*, 2025 edition.
- NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2025 edition.

NFPA 14, *Standard for the Installation of Standpipe and Hose Systems*, 2024 edition.

NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection*, 2022 edition.

NFPA 17, *Standard for Dry Chemical Extinguishing Systems*, 2024 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection*, 2025 edition.

NFPA 22, *Standard for Water Tanks for Private Fire Protection*, 2023 edition.

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances*, 2025 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, 2023 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2024 edition.

NFPA 30B, *Code for the Manufacture and Storage of Aerosol Products*, 2023 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment*, 2024 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*, 2024 edition.

NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids*, 2024 edition.

NFPA 36, *Standard for Solvent Extraction Plants*, 2025 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 2024 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 2024 edition.

NFPA 54, *National Fuel Gas Code*, 2024 edition.

NFPA 58, *Liquefied Petroleum Gas Code*, 2024 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2023 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2024 edition.

NFPA 70®, *National Electrical Code®*, 2023 edition.

NFPA 72®, *National Fire Alarm and Signaling Code®*, 2025 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2024 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives*, 2025 edition.

NFPA 82, *Standard on Incinerators and Waste and Linen Handling Systems and Equipment*, 2024 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code*, 2023 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 2023 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids*, 2020 edition.

NFPA 101®, *Life Safety Code®*, 2024 edition.

NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*, 2023 edition.

NFPA 204, *Standard for Smoke and Heat Venting*, 2024 edition.

NFPA 220, *Standard on Types of Building Construction*, 2024 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2024 edition.

NFPA 252, *Standard Methods of Fire Tests of Door Assemblies*, 2022 edition.

NFPA 400, *Hazardous Materials Code*, 2025 edition.

NFPA 495, *Explosive Materials Code*, 2023 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 2024 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, 2024 edition.

NFPA 600, *Standard on Facility Fire Brigades*, 2025 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2022 edition.

NFPA 750, *Standard on Water Mist Fire Protection Systems*, 2023 edition.

NFPA 1081, *Standard for Facility Fire Brigade Member Professional Qualifications*, 2024 edition.

NFPA 1125, *Code for the Manufacture of Model Rocket and High-Power Rocket Motors*, 2022 edition.

NFPA 1660, *Standard for Emergency, Continuity, and Crisis Management: Preparedness, Response, and Recovery*, 2024 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, 2025 edition.

NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*, 2023 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*, 2025 edition.

NFPA 5000®, *Building Construction and Safety Code*®, 2024 edition.

2.3 Other Publications.

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

AMCA Standard 99, *Standards Handbook*, 2016. (Supersedes AMCA Standard 99-0401.)

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

ANSI/ASME B31.1, *Power Piping*, 2022.

ASME B31.3, *Process Piping*, 2022.

Boiler and Pressure Vessel Code, 2023.

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

ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*, 2010, reapproved 2016.

ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*, 2022.

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, 2022.

ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, 2019.

ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, 2014, reapproved 2022.

ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, 2003, reapproved 2019.

ASTM F1002, *Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*, 2015, reapproved 2021.

ISO/ASTM 52900, *Additive Manufacturing — General Principles — Fundamentals and Vocabulary*, 2021.

2.3.4 BSI Publications. BSI British Standards, 12950 Worldgate Drive, Suite 800, Herndon, VA 20170.

BS EN 17348, *Requirements for design and testing of vacuum cleaners for use in potentially explosive atmospheres*, 2022.

2.3.5 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)*, 2018.

2.3.6 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: Safety Instrumented Systems for the Process Industry Sector*, 2004.

2.3.7 MSHA Publications. Mine Safety and Health Administration (MSHA), 201 12th Street South, Suite 401, Arlington VA 22202-5450.

MSHA Title 30, Code of Federal Regulations, Part 18, Section 12.18.6.5 and Section 18.65, "2G Test."

2.3.8 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

UL 4040, *Outline of Investigation for Portable Wet-Type Dust Collectors for Collection of Combustible Metals*, 2016.

UL/CSA 60335-2-69, *Household and similar electrical appliances — Safety — Part 2-69: Particular requirements for wet and dry vacuum cleaners, including power brush for commercial use*, 2022.

2.3.9 UN Publications. United Nations Publications Customer Service, P.O. Box 960, Herndon, VA 20172.

Recommendations on the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria, 2019.

2.3.10 US Government Publications. US 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."

2.3.11 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2020.

2.4 References for Extracts in Mandatory Sections.

NFPA 30, *Flammable and Combustible Liquids Code*, 2024 edition.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 2023 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2024 edition.

NFPA 70®, *National Electrical Code*®, 2023 edition.

NFPA 77, *Recommended Practice on Electricity*, 2024 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, 2024 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 2024 edition.

NFPA 921, *Guide for Fire and Explosion Investigations*, 2024 edition.

NFPA 1250, *Recommended Practice in Fire and Emergency Service Organization Risk Management*, 2020 edition.

NFPA 1451, *Standard for a Fire and Emergency Service Vehicle Operations Training Program*, 2018 edition.

NFPA 2112, *Standard on Flame-Resistant Clothing for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*, 2023 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*, 2025 edition.

Chapter 3 Definitions

3.1 General.

3.1.1 The definitions contained in this chapter shall apply to the terms used in this standard.

3.1.2 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.

3.1.3 *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 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 phrases “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.

3.3.1* Abort Gate. A device for the quick diversion of material or air to the exterior of a building or other safe location upon detection of an ignition source in a duct. (CMD-FUN)

3.3.2* Additive Manufacturing (AM). The process of joining materials to make parts from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing and formative manufacturing methodologies. [ISO/ASTM 52900, 2021] (CMD-FUN)

3.3.3* Agricultural Combustible Dust. Any finely divided solid agricultural material that presents a flash fire hazard or explosion hazard when suspended and ignited in air. (CMD-AGR)

3.3.4 Airflow Control Valve. A device utilized to maintain design pneumatic transport velocities or face velocities at pick up point(s). (CMD-FUN)

3.3.5* Air-Material Separator (AMS). A device designed to separate the conveying air/gas from the material being conveyed. (CMD-FUN)

3.3.5.1* Cyclone. A device that uses geometry (i.e., shape) and centrifugal force to separate the conveying air/gas from the material being conveyed. (CMD-FUN)

3.3.5.2 Dry-Type Air-Material Separator (AMS). See 3.3.5.3, Dust Collector. (CMD-FUN)

3.3.5.3* Dust Collector. A device that uses filter media to separate the conveying air/gas from the material being conveyed. (CMD-FUN)

3.3.5.4* Enclosureless AMS. A device using filter media to separate the conveying air/gas from the material being conveyed but without full physical enclosure of the filter media. (CMD-FUN)

3.3.5.5* Filter Receiver. A dust collector designed for bulk material flow such as products conveying or a central vacuum system. (CMD-FUN)

3.3.5.6 Media Collector. See 3.3.5.3, Dust Collector. (CMD-FUN)

3.3.5.7 Point-of-Use Dust Collector. A dust collector attached to dust-producing equipment, usually with an integral AMD used to create negative pressure. (CMD-AGR)

3.3.5.8 Portable Air-Material Separator (AMS). A portable device used as a dust collector. (CMD-FUN)

3.3.5.9* Portable Vacuum Cleaner. A movable assembly consisting of a vacuum source (AMD), an AMS within an enclosure, and a vacuum hose, used to remove dusts and particles from surfaces. (CMD-FUN)

3.3.5.10* Wet Scrubber (Wet-Type AMS). A device that uses liquid to separate the conveying air/gas from the material being conveyed. (CMD-FUN)

3.3.5.11 Wet-Type Air-Material Separator. See 3.3.5.10, Wet Scrubber. (CMD-FUN)

3.3.6* 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. (CMD-FUN)

3.3.7 Aluminum Paste. See 3.3.92.1. (CMD-CMM)

3.3.8 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. (CMD-FUN)

3.3.9 Bucket Elevator. An enclosed vertical conveyor using a belt with buckets or cups attached, with a head pulley and a tail pulley. (CMD-FUN)

3.3.10* Bulk Raw Grain. Grain materials that have not undergone processing or size reduction. (CMD-AGR)

3.3.11 Castings (Metal). An object or finished shape obtained by solidification of a metallic substance in a mold. (CMD-CMM)

3.3.11.1* Heavy Casting (Metal). Castings greater than 25 lb (11.3 kg) with walls of large cross-sectional dimensions [at least 1/4 in. (6.4 mm)]. (CMD-CMM)

3.3.12* 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). (CMD-FUN)

3.3.13* Chips (Metal). Particles produced from operations cutting or machining metal that are not oxidized and that are not diluted by noncombustible materials. (CMD-CMM)

3.3.14* Combustible Dust. A finely divided combustible particulate solid, including combustible fibers/flyings, that presents a flash fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. (CMD-FUN)

3.3.15* Combustible Metal. Any metal composed of distinct particles or pieces, regardless of size, shape, or chemical composition, that will burn. (CMD-FUN)

3.3.15.1* Combustible Metal Dust. A combustible metal particulate solid, including combustible fibers/flyings, that presents a fire, flash fire, or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations. (CMD-CMM)

3.3.15.2 Combustible Metal Particulate. See 3.3.15.1, Combustible Metal Dust. (CMD-CMM)

3.3.15.3* Metal Dust. Metal particulate resulting from a solid state secondary processing operation. (CMD-CMM)

3.3.16* 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. (CMD-FUN)

3.3.17 Combustion Chamber. Enclosure where the combustion takes place and the fuel energy is liberated in the form of heat. (CMD-WOO)

3.3.18 Compartment. A subdivision of an enclosure. (CMD-FUN)

3.3.19 Compartmentation. The interposing of a physical barrier that is not required to be fire or explosion resistant in order to limit combustible particulate solid migration and hence to control the size of a hazard area. (CMD-FUN)

3.3.20 Competent Ignition Source. An ignition source that has sufficient energy and is capable of transferring that energy to the fuel long enough to raise the fuel to its ignition temperature. [921, 2024] (CMD-FUN)

3.3.21* Conductive. Possessing the ability to allow the flow of an electric charge. (CMD-FUN)

3.3.21.1 Conductive Dusts. Dusts with a volume resistivity of less than 10^5 ohm-m. (CMD-FUN)

3.3.21.2 Conductive Particulate Solids. Particulate solids with a volume resistivity of less than 10^5 ohm-m. (CMD-FUN)

3.3.22 Conductor. A material or object that allows an electric charge to flow easily through it. [77, 2024] (CMD-FUN)

3.3.23* Critical Process. A process that has the potential to cause harm to personnel, equipment, structures, or product in the event of an uncontrolled failure. (CMD-CMM)

3.3.24* Damage-Limiting Construction. A building construction method that incorporates exterior wall or roof sections, or both, designed to relieve deflagration pressures without jeopardizing the structural integrity of the building and without allowing the deflagration to propagate into adjacent interior spaces. (CMD-FUN)

3.3.25* Deflagration. Propagation of a combustion zone at a velocity that is less than the speed of sound in the unreacted medium. [68, 2023] (CMD-FUN)

3.3.26* Deflagration Hazard. A place or area where there is all of the following:

- (1) A particulate capable of propagating deflagration by virtue of particle size, shape, and chemistry
- (2) A means of suspending the particulate in an oxidizing atmosphere
- (3) Sufficient particulate to exceed the minimum explosible concentration
- (4) A potential competent ignition source or mechanism. (CMD-FUN)

3.3.27 Deflagration Hazard Area.

3.3.27.1* Dust Explosion Hazard Area. A room or building volume where an unvented deflagration of the entrainable dust mass can result in a pressure exceeding the strength of the weakest structural element not intended to fail. (CMD-FUN)

3.3.27.2* Dust Flash Fire Hazard Area. An area where combustible dust accumulation on exposed or concealed surfaces, external to equipment or containers, can result in personnel injury from thermal dose during a dust flash fire, as well as any areas where a dust cloud of a hazardous concentration exists. (CMD-FUN)

3.3.28 Deflagration Index. Value indicated by the use of the variable K_{St} . (See 3.3.68, K_{St} .) (CMD-FUN)

3.3.29 Detachment. A hazard management strategy in which the hazard is located in a separate building or an outside area, removed from other structures to be protected by a distance as required by this standard. (CMD-FUN)

3.3.30* Dissipative. A material or a construction that will reduce static charge to acceptable levels. [77, 2024] (CMD-FUN)

3.3.31 Dryer. A piece of processing equipment using temperature or pressure change to reduce the moisture or volatile content of the material being handled. (CMD-FUN)

3.3.32 Duct. Pipes, tubes, or other enclosures used to convey materials pneumatically or by gravity. (CMD-FUN)

3.3.33* Dust Collection System. A combination of equipment designed to capture, contain, and control airborne dust, and pneumatically convey the captured dust to an air-material separator (AMS). (CMD-FUN)

3.3.34* 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. (CMD-FUN)

3.3.35* 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. (CMD-FUN)

3.3.36* Enclosure. A confined or partially confined volume. [68, 2023] (CMD-FUN)

3.3.37 Eutectic Reaction. (Reserved) (CMD-CMM)

3.3.38* Explosible. Capable of propagating a deflagration when dispersed in air or the process-specific oxidizing media. (CMD-FUN)

3.3.39 Explosion. The bursting or rupture of an enclosure or container due to the development of internal pressure from a deflagration. [69, 2024] (CMD-FUN)

3.3.40* Explosive-Actuated Device. Any tool or special mechanized device that is actuated by explosive materials or that releases and directs work through an explosive charge. (CMD-FUN)

3.3.41 Fibers/Flyings.

3.3.41.1* Combustible Fibers/Flyings. Fibers/flyings where any dimension is greater than 500 μm in nominal size, which can form an explosible mixture when suspended in air at standard atmospheric pressure and temperature. [499, 2024] (CMD-FUN)

3.3.41.2* Ignitable Fibers/Flyings. Fibers/flyings where any dimension is greater than 500 μm in nominal size, which are not likely to be in suspension in quantities to produce an explosible mixture, but could produce an ignitable layer fire hazard. [499, 2024] (CMD-FUN)

3.3.42 Fines (Metal). The portion of a powder composed of particles that are smaller than 45 μm (US Standard Sieve No. 325); also known as the subsieve size fraction. (CMD-CMM)

3.3.42.1 Superfines (Metal). Particles smaller than 10 μm . (CMD-CMM)

3.3.42.2 Ultrafines (Metal). Particles with size generally less than 0.1 μm . (CMD-CMM)

3.3.43* 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. (CMD-FUN)

3.3.44* Fire-Resistive. Meeting the requirements for Type I or Type II construction. (CMD-FUN)

3.3.45* Flame Resistance. The property of a material whereby combustion is prevented, terminated, or inhibited following the application of a flaming or nonflaming source of ignition, with or without subsequent removal of the ignition source. [2113, 2025] (CMD-FUN)

3.3.46 Flake (Metal). A flat or scale-like particulate material that is relatively thin with a large aspect ratio. (CMD-CMM)

3.3.47* Flash Fire. A deflagration that spreads by means of a flame front rapidly through a diffuse fuel, such as dust, gas, or the vapors of an ignitable liquid, without the production of damaging pressure. (CMD-FUN)

3.3.48* Flash Fire. See 3.3.47. (CMD-CMM)

3.3.49 Floor Sweep. A suction hood located on the floor with an opening to allow floor sweepings to enter the dust collection system. (CMD-WOO)

3.3.50 Food. According to the United States FDA, (1) articles used for food or drink for man or other animals, (2) chewing gum, and (3) articles used for components of any such article. (CMD-AGR)

3.3.51 Fuel Object. A combustible object or mass of particulate that can serve as a source of fuel for a fire; sometimes referred to as a *fuel package*. (CMD-FUN)

3.3.52 Fugitive Dusts. Dust that escapes from equipment and containers. (CMD-FUN)

3.3.53* Garments. Clothing including, but not limited to, coveralls, trousers, shirts, and outerwear. [2112, 2023] (CMD-FUN)

3.3.54 Green Material. Wood particulate that has an average moisture content equal to or greater than 25 percent by weight (wet basis). (CMD-WOO)

3.3.55 Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection. [70, 2023] (CMD-FUN)

3.3.56 Handling (Metal). Any activity, including processing, that can expose the metal's surface to air or to any other substance capable of reacting with the metal under the conditions of the exposure. (CMD-CMM)

3.3.57 Hazards Analysis. A documented assessment performed by personnel knowledgeable of the specific hazards of the material and that is acceptable to the AHJ. (CMD-FUN)

3.3.58 Headhouse. The building or enclosure where grain-handling equipment (e.g., conveyors, legs, scales, cleaners) is located and where grain is lifted by one or more elevator legs

and discharged into a bin or grain-handling equipment. (CMD-AGR)

3.3.59* Hog (Wood Hog). A machine used to grind or reduce the size of wood, scrap wood, or other feed stock. (CMD-WOO)

3.3.60 Hot Work. Work involving burning, welding, or a similar operation that is capable of initiating fires, flash fires, or explosions. (CMD-FUN)

3.3.61* 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, 2023] (CMD-FUN)

3.3.62* Identified (as applied to equipment). Recognizable as suitable for the specific purpose, function, use, environment, application, and so forth, where described in a particular code requirement. [70, 2023] (CMD-FUN)

3.3.63* Ignitable Liquid. Any liquid or liquid mixture that has a measurable closed-cup flash point. [30, 2024] (CMD-FUN)

3.3.64 Incipient-Stage Fire. A fire that is in the initial or beginning stage and that can be controlled or extinguished by portable extinguishers or small amounts of dry extinguishing agents, without the need for protective clothing or breathing apparatus. (CMD-FUN)

3.3.65* Ingredient Transport System. A pneumatic conveying system and AMS dedicated to the transport of clean food ingredients or mixtures from one storage location inside a facility to another location in the facility. (CMD-AGR)

3.3.66 Intermediate Bulk Containers.

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

3.3.66.1.1 Type A FIBC. An FIBC made from nonconductive fabric with no special design features for control of electrostatic discharge hazards. (CMD-FUN)

3.3.66.1.2 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. (CMD-FUN)

3.3.66.1.3 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. (CMD-FUN)

3.3.66.1.4 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. (CMD-FUN)

3.3.66.2* 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. (CMD-FUN)

3.3.66.2.1 Insulating RIBC. An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded. (CMD-FUN)

3.3.67 Kiln Dryers. Large heated rooms or enclosures intended to reduce or control the moisture content of lumber and hardboard products. (CMD-WOO)

3.3.68* K_{st} . The deflagration index of a dust cloud. [68, 2023] (CMD-FUN)

3.3.69* Limiting Oxidant Concentration (LOC). The concentration of oxidant in a fuel-oxidant-diluent mixture below which a deflagration cannot occur under specified conditions. [69, 2024] (CMD-FUN)

3.3.70 Locations, Hazardous (Classified). [Hazardous (Classified) Locations] Locations where fire or explosion hazards might exist due to flammable gases, flammable liquid-produced vapors, combustible liquid-produced vapors, combustible dusts, combustible fibers/flyings, or ignitable fibers/flyings. [70, 2023] (CMD-FUN)

3.3.71 Locations, Unclassified. (Unclassified Locations) Locations determined to be neither Class I, Division 1; Class I, Division 2; Zone 0; Zone 1; Zone 2; Class II, Division 1; Class II, Division 2; Class III, Division 1; Class III, Division 2; Zone 20; Zone 21; Zone 22; nor any combination thereof. [70, 2023] (CMD-FUN)

3.3.72* Lower Flammable Limit (LFL). The lowest concentration of a combustible substance in a gaseous oxidizer that will propagate a flame, under defined test conditions. [68, 2023] (CMD-FUN)

3.3.73 Management of Change (MOC). A management system that requires the evaluation of proposed changes to process materials, staffing, job tasks, technology, equipment, procedures, and facilities to evaluate the potential safety significance of the change, to identify any additional needed safety controls, and to identify changes to other management systems required to safely implement the change. (See A.8.11.1.) (CMD-FUN)

3.3.74 Marine Tower. Stationary or movable tower used for supporting equipment to load or unload grain. (CMD-AGR)

3.3.75* Mesh Size. The dimensions of a mesh that are specified in ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*. (CMD-FUN)

3.3.76* Metal. Pure metal or alloys having the generally recognized properties of the metal, including the fire or explosion characteristics of the metal in its various forms. (CMD-CMM)

3.3.76.1 Alkali Metals. Cesium, francium, lithium, potassium, rubidium, sodium, and alloys of these metals, such as NaK. (CMD-CMM)

3.3.76.2* Legacy Metals. The metals aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium. (CMD-CMM)

3.3.76.3 Metal Alloy. A multiphase solid that is formed by mixing in the molten state, in which the primary component or matrix phase is a metal and the original composition is retained during size reduction. (CMD-CMM)

3.3.76.4* Metal-Containing Mixture. A physical combination of one or more metals or metal alloys with one or more solid, liquid, or semi-solid chemical elements or compounds. (CMD-CMM)

3.3.77 Metal Vapor Condensate. Solidified particles resulting from the evaporation of metal alloys during the laser powder bed fusion additive manufacturing (AM) process. (CMD-CMM)

3.3.78* 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. (CMD-FUN)

3.3.79* 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. (CMD-FUN)

3.3.80* Mixture. A combination of particulates incorporating more than one material. (CMD-FUN)

3.3.81* Moisture Content (Wet Basis). The maximum percentage of water that can be driven off a sample through drying as a percentage of the original sample weight. (CMD-WOO)

3.3.82* Nanometal Powder. Any metal powder produced with a characteristic size smaller than 500 nanometers (0.5 μm), which can include powders where only a fraction of the material produced is less than 500 nanometers (0.5 μm). (See also 22.14.2.2.) (CMD-CMM)

3.3.83 Nanopowder. See 3.3.125, Ultrafine Particle. (CMD-FUN)

3.3.84* Noncombustible Material. A material that, in the form in which it is used and under the conditions anticipated, will not ignite, support combustion, burn, or release flammable vapors when subjected to fire or heat. (CMD-FUN)

3.3.85* Nonconductive. A material or a construction that has the ability to accumulate charge, even when in contact with ground. (CMD-FUN)

3.3.86 Ohm-meter (Ohm-m). The term used to define electrical volume resistivity of a material. (CMD-FUN)

3.3.87 Ohms per Square. The term used to define electrical surface resistivity of a material. (CMD-FUN)

3.3.88 Operational Readiness Review. A management system to verify that all required conditions exist and required safety tasks have been completed so that new, modified, or formerly idled facilities can be safely started up. (CMD-FUN)

3.3.89 Outside Bucket Elevator (Leg). A bucket elevator that has less than 20 percent of the abovegrade leg height inside any enclosed structure. (CMD-AGR)

3.3.90 Owner/Operator. The organization with fiscal responsibility for the operation, maintenance, and profitability of the facility. (CMD-FUN)

3.3.91 Passivation. A controlled process by which a barrier coating is placed on the surface of the metal to inhibit reaction. (CMD-CMM)

3.3.91.1 Oxygen Passivation. A controlled process that exposes the metal powder to oxygen with the goal of forming an oxide of the metal on the particle surface. (CMD-CMM)

3.3.92 Paste. A mixture consisting of a liquid and suspended particles or flakes. (CMD-CMM)

3.3.92.1 Aluminum Paste. Aluminum flake pigment homogeneously incorporated in a solid or liquid carrier in such a way so as to have a nonflowing product without a free-flowing liquid. (CMD-CMM)

3.3.93* 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. (CMD-FUN)

3.3.93.1 Negative-Pressure Pneumatic Conveying System. A pneumatic conveying system that transports material by utilizing gas at less than atmospheric pressure. (CMD-FUN)

3.3.93.2 Positive-Pressure Pneumatic Conveying System. A pneumatic conveying system that transports material by utilizing gas at greater than atmospheric pressure. (CMD-FUN)

3.3.94* Powder (Metal). Particles of matter intentionally manufactured to a specific size and shape. (CMD-CMM)

3.3.94.1* Aluminum Flake Powder. See 3.3.94.3, Aluminum Powder. (CMD-CMM)

3.3.94.2 Aluminum Granular Powder. See 3.3.94.3, Aluminum Powder. (CMD-CMM)

3.3.94.3* Aluminum Powder. Aluminum powder is divided into three broad classifications: atomized, flake, and granules. (CMD-CMM)

3.3.94.4* Combustible Metal Powder. A combustible particulate metal, regardless of particle size or shape, that is an intentional product and will burn as determined by testing conducted in accordance with Chapter 5 and Section 22.5. (CMD-CMM)

3.3.94.5 Tantalum Powder. Nodular or flake-like tantalum particles that will pass through a 20 mesh screen (850 μm) as discrete particles or as agglomerates of discrete particles. (CMD-CMM)

3.3.94.5.1 Unrefined Tantalum Powder. Any tantalum powder that contains impurities, such that further refinement is required to produce a tantalum product suitable for commercial use. (CMD-CMM)

3.3.95* Powder Production Plant. Facilities or buildings in which the primary product is powder. (CMD-CMM)

3.3.96* Propellant-Actuated Device. Any tool or special mechanized device or gas generator system that is actuated by a smokeless propellant or combustion of a confined fuel-air mixture, or that releases and directs work through a smokeless propellant charge. (CMD-FUN)

3.3.97* Pyrophoric Material. See 3.3.98. (CMD-CMM)

3.3.98 Pyrophoric Material. A material that ignites upon exposure to air at or below 130°F (54.4°C). (CMD-FUN)

3.3.99 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] (CMD-FUN)

3.3.100* Recycling. Processing, reprocessing, resizing, sorting, sifting, or staging of scrap materials formerly in the process stream or in use, that no longer serve their original and/or intended purpose, but continue to have resale value. (CMD-FUN)

3.3.101 Replacement-in-Kind. A replacement that satisfies the design specifications of the replaced item. (CMD-FUN)

3.3.102 Ribbon. A manufactured product or a continuous chip resulting from secondary processing (e.g., boring, grinding, milling, turning), of a ductile material. (CMD-CMM)

3.3.102.1* Magnesium Ribbon. Magnesium metal that is less than 1/8 in. (3.2 mm) in two dimensions or less than 1/20 in. (1.3 mm) in single dimension, also considered a powder for the purpose of this standard. (CMD-CMM)

3.3.103* Risk Assessment. An assessment of the likelihood, vulnerability, and magnitude of the incidents that could result from exposure to hazards. [1250, 2020] (CMD-FUN)

3.3.104 Screening Test. For the purposes of this standard, a test performed to determine whether a material or mixture exhibits fire-, explosion-, or water-reactivity-related characteristics. (CMD-FUN)

3.3.105 Segregation. A hazard management strategy in which a physical barrier is established between the hazard area and an area to be protected. (CMD-FUN)

3.3.106 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. (CMD-FUN)

3.3.107 Size Reduction Equipment(Sulfur). Any machinery that reduces the size of particles by compression, impact, attrition, or similar processes. (CMD-HAP)

3.3.107.1* Attrition-Style Size Reduction Equipment. Pulverizers that do not depend on moving parts for their disintegrating action, such as attrition mills. (CMD-HAP)

3.3.107.2 Compression-Style Size Reduction Equipment. Low-speed primary crushers, such as jaw and roll crushers. (CMD-HAP)

3.3.107.3 Impact-Style Size Reduction Equipment. High-speed primary crushers, such as disk and hammer mills, pulverizers, and fine size reduction equipment of all kinds, except attrition. (CMD-HAP)

3.3.108* Spark. A localized source of thermal or electrical energy capable of igniting combustible material. (CMD-FUN)

3.3.108.1* 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. (CMD-FUN)

3.3.108.2* 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. (CMD-FUN)

3.3.109* Spark-Resistant Material. A material that is not prone to generate impact sparks under conditions of use. (CMD-FUN)

3.3.110* Sponge. A porous metal product obtained by processing metal ore prior to being melted. (CMD-CMM)

3.3.111 Spontaneous Heating. Process whereby a material increases in temperature without drawing heat from its surroundings. [921, 2024] (CMD-FUN)

3.3.112 Static Dissipative. See 3.3.30, Dissipative. (CMD-FUN)

3.3.113 Stuck Lumber. Lumber storage piles with 1 in. (2.5 cm) runners perpendicular to the storage at every level. (CMD-WOO)

3.3.114* Sulfur Dust. Finely divided sulfur that presents a fire or deflagration hazard when suspended in air or other oxidizing medium over a range of concentrations regardless of particle size or shape. (CMD-HAP)

3.3.115 Swarf. Particles produced from a cutting, machining, or grinding operation that causes partial oxidation of the parent material or dilution by other inert materials. (CMD-CMM)

3.3.116 Tantalum Powder. See 3.3.94.5. (CMD-CMM)

3.3.117 Tantalum Ultrafines. (Reserved) (CMD-CMM)

3.3.118 Thermal Oil Heating System. A thermal oil heating system is a closed loop circulating system that heats an ignitable (flammable or combustible) fluid and transports it to utilization equipment for the purpose of transferring its heat to the equipment. (CMD-WOO)

3.3.118.1 Nonvaporizing Thermal Oil Heating System. A thermal oil heating system that is designed to operate with the heated oil below its atmospheric boiling point. (CMD-WOO)

3.3.118.2 Vaporizing Thermal Oil Heating System. A thermal oil heating system that is designed to heat the oil above its atmospheric boiling point as it passes through the heater. (CMD-WOO)

3.3.119 Thermal Oil Used as Heat Transfer Fluid. An organic or synthetic fluid that is ignitable (flammable or combustible) and that is used as a medium to transfer heat energy from a heater or vaporizer to a remote heat consumer. (CMD-WOO)

3.3.120* Thermite Reaction. The exothermic reaction between a metal and any metal oxide lower in the electromotive series. (CMD-CMM)

3.3.121 Threshold Housekeeping Dust Accumulation Limit. The maximum quantity of dust permitted to be present before cleanup is required. (CMD-FUN)

3.3.122 Titanium Fines. (Reserved) (CMD-CMM)

3.3.123 Transient Releases. A short duration, episodic release of material from the process equipment that poses a fire, flash fire, or explosion hazard. (CMD-FUN)

3.3.124 Ullage Space. The open space above the surface of the stored solids in a storage vessel. (CMD-FUN)

3.3.125* Ultrafine Particle. Individual particles that have a median size, in two or three dimensions, less than 0.5 µm (500 nm). (CMD-FUN)

3.3.126 Vent Closure. A pressure-relieving cover that is placed over a vent. [68, 2023] (CMD-FUN)

3.3.127 Vented Explosion Pressure (P_{red}). The maximum pressure developed in a vented enclosure during a vented deflagration. (CMD-FUN)

3.3.128 Wall.

3.3.128.1 Fire Barrier Wall. A wall, other than a fire wall, having a fire resistance rating. [221, 2024] (CMD-FUN)

3.3.128.2 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, 2024] (CMD-FUN)

3.3.129* Water-Compatible. A material that is neither reactive with water nor incompatible with water and that, consequently, can be extinguished with a water-based extinguishing system. (CMD-FUN)

3.3.130* Water-Incompatible. A material that does not chemically react with water, but which undergoes a change of phase or state upon mixture with water that renders it permanently changed or incompatible with the remainder of the process. (CMD-FUN)

3.3.131* Water-Reactive. A material that chemically reacts with water, producing another compound that can represent a different set of fire protection concerns. (CMD-FUN)

3.3.132 Wood. The cellulosic material derived from trees, and other cellulosic materials including, but not limited to, wheat straw, flax, bagasse, coconut shells, corn stalks, hemp, rice hulls, and paper or other cellulosic fiber used as a substitute or additive to wood. (CMD-WOO)

3.3.133 Wood Dust. (CMD-WOO)

3.3.133.1* Deflagrable Wood Dust. Wood particulate that will propagate a deflagration flame front, when suspended in air, or the process-specific oxidizing medium, in sufficient concentration, thus presenting a deflagration hazard. (CMD-WOO)

3.3.133.2 Dry Nondeflagrable Wood Dust. Wood particulate having a moisture content of less than 25 percent (wet basis) and a particle size that will not propagate deflagration. (CMD-WOO)

3.3.133.3 Wood-Derived Materials. These materials include but are not limited to sawdust, sanderdust, planer shavings, hoggings, wood flour, and moulder waste. (CMD-WOO)

3.3.134 Zirconium Fines. (Reserved) (CMD-CMM)

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 fire, flash fire, and explosion hazards in accordance with Chapter 7
- (3) Managing the identified fire, flash fire, and explosion hazards in accordance with the objectives in Section 4.2
- (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 or explosion 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, Explosions, or Releases of Hazardous Materials. The facility and processes shall be designed to prevent fires, explosions, or releases of hazardous materials that can cause failure of adjacent compartments, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements.

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

4.2.3.2 The structure shall be located, designed, constructed, equipped, and maintained to prevent the propagation of fire or explosion to or from adjacent storage or structures.

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

- (1) The prescriptive requirements in Chapters 5, 7, and 8
- (2)* A hazard management program in conformance with the prescriptive requirements of Chapter 9 and the prescriptive hazard management requirements of the relevant industry- or commodity-specific chapter, or that meets the objectives of Chapter 4 and the relevant industry- or commodity-specific chapter through a performance-based design in accordance with Chapter 6

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

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

4.2.7 Where an industry- or commodity-specific chapter addresses hazards not associated with combustible dusts or particulate solids, those hazards 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 explosive.

5.1.1 Where dusts are determined to be combustible or explosive, 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 explosive, 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* Where the owner or operator does not have prior knowledge of combustibility or explosibility, the analysis of representative samples in accordance with the requirements of 5.4.1 and 5.4.3 shall be conducted to determine if the material is in a combustible or explosive form.

5.2.2* The determination of combustibility or explosibility shall be permitted to be based upon historical facility data or published data that are deemed to be representative of current materials and process conditions.

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

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

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

5.3* Self-Heating and Reactivity Hazards. Where self-heating, thermal instability, water reactivity, or chemical reactivity hazards exist, the process, storage, and transport conditions shall be controlled to prevent a fire, explosion, or toxic exposure.

5.3.1 Self-Heating Hazard Evaluations.

5.3.1.1 A documented self-heating hazard evaluation shall be performed where one or more of the following conditions is present:

- (1) Bulk storage or transport of combustible particulate solids in quantities of 1000 kg (2203 lb) or larger
- (2) More than 10 kg (22 lb) of material is present in dryer discharge bins and hoppers at elevated temperatures
- (3) A potential self-heating scenario has been identified in the DHA

5.3.1.2 The self-heating hazard evaluation method shall be according to 5.3.1.2.1 or according to 5.3.1.2.2 and 5.3.1.2.3.

5.3.1.2.1 A documented review shall be conducted of experience storing and transporting the bulk material in quantities comparable to or larger than those used in the facility, at temperatures comparable to or higher than the expected storage or transport temperatures, and for durations comparable to or longer than the expected storage or transport duration.

5.3.1.2.2* Laboratory tests shall be conducted to determine self-heating potential and rate.

5.3.1.2.3* A theoretically based scaling analysis shall be conducted using the laboratory test data to determine the critical temperatures for self-heating at the scale being used at the facility.

5.3.2 Thermal Instability Hazard Evaluations.

5.3.2.1 A thermal instability hazard evaluation shall be conducted when one or more of the following conditions exist:

- (1) More than 1000 kg (2200 lb) of combustible particulate are stored for longer than 8 hours in a bin or hopper or bulk pile at a temperature higher than 30°C (104°F).
- (2) More than 100 kg (220 lb) of particulate product are in an oven or dryer for more than 1 hour.
- (3) A scenario where heated material can reside for extended periods of time in process equipment has been identified in the DHA.

5.3.2.2 The thermal instability hazard evaluation method shall be according to either 5.3.2.2.1 or 5.3.2.2.2.

5.3.2.2.1 A documented review of pertinent reactivity literature, safety data sheets, and operating experience shall be conducted, identifying the reactivity of the material, thermal decomposition onset temperature, and, where possible, the reaction byproducts including gases that could be toxic, corrosive, or flammable.

5.3.2.2.2* Temperature sensitivity testing shall be conducted at temperatures that would correspond to the highest possible temperature the material could attain based on exposure conditions determined from the DHA.

5.3.3 Water Reactivity Hazard Evaluations.

5.3.3.1 A water reactivity hazard evaluation shall be conducted when one or both of the following conditions exist:

- (1) A water-based fire suppression system is used for the combustible particulate material.
- (2) Particulate product or dust is exposed to process water, condensed water vapor, or outdoor precipitation.

5.3.3.2 The water reactivity hazard evaluation method shall be according to either 5.3.3.2.1 or 5.3.3.2.2.

5.3.3.2.1* A documented review of pertinent reactivity literature, reactivity screening software, and operating experience shall be conducted, identifying the reactivity of the material and, where possible, the reaction byproducts including gases that could be toxic, corrosive, or flammable.

5.3.3.2.2 Water reactivity testing shall be conducted using the *UN Recommendations on the Transport of Dangerous Goods, Model Regulations — Manual of Tests and Criteria* water reactivity Test N.5 for potential Division 4.3 water-reactive materials that emit flammable gases, or another test acceptable to the AHJ.

5.3.4 Chemical Reactivity Hazard Evaluations.

5.3.4.1 A chemical reactivity hazard evaluation shall be conducted when particulate product or dust could be exposed to an incompatible material or a reactivity scenario has been otherwise identified in the DHA.

5.3.4.2 The chemical reactivity hazard evaluation method shall be according to either 5.3.4.2.1 or 5.3.4.2.2.

5.3.4.2.1 A documented review of pertinent reactivity literature, reactivity screening software, and operating experience

shall be conducted, identifying the reactivity of the material and, where possible, the reaction byproducts including gases that could be toxic, corrosive, or flammable. (See A.5.3.3.2.1.)

5.3.4.2.2* Calorimetry testing shall be used for determining potential chemical reactivity hazards.

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 (Fire Hazard Potential).

5.4.1.1 Where the combustibility is not known, determination of fire hazards of a layer of material shall be determined by one of the following tests:

- (1)* A 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,” Section 33.2.4.3.1.
- (2)* Other fire/combustibility test methods that provide an equivalent result for a powder layer acceptable to the authority having jurisdiction.

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.

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. (See A.5.4.3.3.)

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 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.

5.5.2.1 Mixtures with a metallic particulate component and not excluded by the criteria of 22.1.1.6.2 shall be treated as a metallic combustible dust in accordance with the relevant sections of Chapter 22.

5.5.2.2 Mixtures consisting of more than 50 percent by mass wood or wood-based particulate with a metallic particulate component and excluded by the criteria of 22.1.1.6.2 shall be treated as a wood dust in accordance with the relevant sections of Chapter 24.

5.5.2.3 Mixtures consisting of more than 50 percent by mass agricultural particulate to be used in foodstuffs with a metallic particulate component and excluded by the criteria of 22.1.1.6.2 shall be treated as an agricultural dust in accordance with the relevant sections of Chapter 21.

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 Chapter 25.

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

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

5.5.3* Representative Samples.

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.

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.

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 and the prescriptive requirements of the relevant industry- or commodity-specific chapter. [See A.4.2.4(2).]

6.1.3 Approved Qualifications. The performance-based design shall be prepared by a qualified person knowledgeable about the affected systems and their associated hazards.

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 6.1.4.1 through 6.1.4.13.

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, Flash Fire, and Explosion Scenarios. Descriptions of combustible dust or particulate solid fire, flash fire, and explosion design scenarios shall be documented.

6.1.4.6 Input Data. Input data to models and assessment methods shall be documented.

6.1.4.7 Output Data. Output data from models and assessment methods 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* Re-evaluation. Performance-based designs and documentation shall be updated and subject to reapproval 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, flash fire, or explosion 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 8.11.

6.1.7.1* This maintenance 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.

6.2.1 The specified performance criteria of Section 6.3 and the specified fire, flash fire, and explosion scenarios of Section 6.4 shall be permitted to be modified by a documented risk assessment.

6.2.2 The AHJ shall be provided with sufficient documentation to support the validity and relevance of the risk assessment methodology when requested by the AHJ.

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. The life safety objectives of 4.2.1 with respect to a fire, flash fire, or explosion hazard shall be achieved if either of the following conditions is met:

- (1) Ignition has been prevented.
- (2) Under all fire, flash fire, or explosion scenarios, no person, other than those in the immediate proximity of the ignition, is exposed to untenable conditions due to the fire, flash fire, or explosion; and for fire or explosion scenarios, 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, flash 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, flash 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, Explosions, or Releases of Hazardous Materials. When limitation of fire, flash fire, and explosion 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, flash 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 mitigation 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 Flash Fire and Explosion Scenarios.

6.4.2.1 Each duct, enclosed conveyor, silo, bunker, AMS, 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 a flash fire and explosion scenario.

6.4.2.2 Each duct, enclosed conveyor, silo, bunker, AMS, 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 a flash fire and 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 a flash fire and 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 a flash fire and explosion scenario.

6.4.2.5* Where combustible dust can cause other flash fire or explosion hazards, those hazards shall be included as flash fire or 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, flash 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 design professional shall establish numerical performance criteria for each of the documented performance objectives established for the design.

6.5.3 For each scenario, 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 sensitivity analysis, given the assumptions.

6.5.4 A sensitivity analysis shall be performed for each assumption that is not provided in an authoritative reference acceptable to the AHJ to show that variation of said assumption does not result in a failure to meet design criteria.

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

Chapter 7 Dust Hazards Analysis (DHA)

7.1* General Requirements.

7.1.1 Retroactivity.

7.1.1.1 The requirements of this chapter and the corresponding X.7 sections of the industry- and commodity-specific chapters shall be applied retroactively.

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

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.

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, flash fire, 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 who possesses documented experience and education regarding methods for performing a DHA and the assessment and identification of mitigation or elimination options for the fire, flash fire, explosion, and related hazards of the specific type or types of combustible dusts involved in the facility.

7.2.3* Documentation.

7.2.3.1 The results of the DHA review shall be documented, including any necessary action items requiring change to the process materials, process operations, equipment, safety systems, or facilities associated with the process.

7.2.3.2 The results of the DHA shall be maintained for the life of 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, flash fire, and explosion scenarios shall include the following:
 - (a) Identification of safe operating ranges
 - (b)* Identification of the safeguards that are in place to manage fire, flash fire, 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. (*See A.5.1.*)

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 flame and pressure propagation between parts of the process system or interconnected systems
- (4) Potential flame and pressure propagation from the process system to the surrounding building or building compartment

7.3.3.2 Each part of the process that could potentially contain all of the following conditions shall be considered a fire hazard and shall be documented as such:

- (1) Combustible particulate solids
- (2) Air or other oxidizing atmosphere
- (3) A competent ignition source

7.3.3.3* Each part of the process that could potentially contain all of the following conditions shall be considered a dust flash fire or explosion hazard and shall be documented as such:

- (1) A combustible particulate solid of sufficiently small particle size and sufficient quantity
- (2) Air or other oxidizing atmosphere
- (3) A competent ignition source
- (4) A credible suspension mechanism

7.3.3.4 Where multiple parts of a process system present essentially the same hazard, a single evaluation shall be permitted to be conducted as representative of all similar parts of the process system.

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 flame and pressure propagation between buildings or building compartments.

7.3.4.2* Each building or building compartment that could potentially contain all of the following conditions shall be considered a fire hazard and shall be documented as such:

- (1) Combustible particulate solids
- (2) Air or other oxidizing atmosphere
- (3) A competent ignition source

7.3.4.2.1* The evaluation of the dust flash fire or explosion hazard in a building or building compartment shall include a comparison of actual or intended dust accumulation to the threshold housekeeping dust accumulation limit that would

present a potential for flash fire exposure to personnel or compartment failure due to explosive overpressure.

7.3.4.2.2 The threshold housekeeping dust accumulation limit and nonroutine dust accumulation levels (e.g., from a process upset) shall be in accordance with relevant industry- or commodity-specific requirements identified in Chapters 21 through 24.

7.3.4.3 Each building or building compartment that could potentially contain all of the following conditions shall be

considered a dust flash fire or explosion hazard and shall be documented as such:

- (1) A combustible particulate solid of sufficiently small particle size
- (2) Air or other oxidizing atmosphere
- (3) A competent ignition source
- (4) A credible suspension mechanism

Chapter 8 Management Systems

8.1* Retroactivity. This chapter and the corresponding X.8 sections of the industry- and commodity-specific chapters shall be applied retroactively to new and existing facilities and processes where the DHA has determined that a combustible dust or particulate solid fire, flash fire, or explosion hazard exists.

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, flash fires, and explosions from combustible dusts or combustible particulate solids.

8.3.2* Operating and maintenance procedures shall address personal protective equipment (PPE), including flame-resistant garments, in accordance with the workplace hazard assessment required by Section 8.6.

8.3.3 Portable Appliances.

8.3.3.1* A written policy shall be established to regulate the use of portable appliances.

8.3.3.2* The policy shall identify locations where specific portable appliances are permitted or prohibited.

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

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

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

8.3.6 The owner/operator shall perform a documented review of operating procedures as often as necessary, but at least annually, to ensure that they remain current and accurate.

8.4 Housekeeping.

8.4.1 General. Housekeeping shall be performed in accordance with Section 8.4 as modified by the corresponding sections in the industry- or commodity-specific chapters.

8.4.2 Methodology.

8.4.2.1 Procedure.

8.4.2.1.1* Documented housekeeping and inspection programs shall be developed, implemented, and updated as required.

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.

8.4.2.1.2.1 Vacuuming shall be the preferred method of cleaning.

8.4.2.1.2.2 Where vacuuming is impractical, permitted cleaning methods shall include sweeping and water washdown.

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

8.4.2.2 Vacuum Cleaning Method.

8.4.2.2.1* Portable Vacuum Cleaners.

8.4.2.2.1.1 Portable vacuum cleaners with a dirty side volume greater than 8 ft³ (0.2 m³) shall comply with 9.8.2 and 9.8.3.

8.4.2.2.1.2* Regardless of industry, when metal particles, dusts, or powders are being cleaned, Chapter 22 shall be the reference source for proper use and limitations of both dry and wet portable vacuum cleaners.

8.4.2.2.1.3* Where used, portable vacuum cleaning devices shall be incorporated into the DHA.

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

8.4.2.2.1.5 All conductive and static-dissipative components, including wands and attachments, shall be bonded and grounded.

8.4.2.2.1.6 Portable vacuum cleaners shall not be used on processes generating hot embers or sparks.

8.4.2.2.1.7* 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.

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

- (1) Materials of construction shall comply with 9.6.6.1.
- (2) Hoses shall be conductive or static dissipative.
- (3) All conductive and static dissipative 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) The vacuum cleaner shall not be operated without filter media in place.
- (6) Electrical motors shall not be located on the dirty side of the primary filtration media or wet separation chamber unless listed for Class II or Class III, Division 1, as appropriate, or Zone 20 or Zone 21 locations.
- (7)* Where liquids or wet materials are picked up by the vacuum cleaner, paper filter elements shall not be used.

8.4.2.2.1.9 Portable air-operated vacuum cleaners that meet the following minimum requirements shall be permitted to be used to collect combustible particulate solids in unclassified and electrically hazardous (classified) areas, provided the following are met:

- (1) Materials of construction comply with 9.6.6.1.
- (2) Hoses are conductive or static dissipative.
- (3) All conductive and static dissipative components, including wands and attachments, are bonded and grounded.
- (4) Where liquids or wet materials are picked up by the vacuum cleaner, paper filter elements are not used.
- (5)* The design of the vacuum cleaner is suitable for use in a hazardous (classified) location.

8.4.2.2.1.10* In combustible dust hazardous (classified) locations, vacuum cleaners shall be listed for combustible dust hazardous (classified) locations.

8.4.2.2.1.11 Where flammable vapors or gases are present in combustible dust hazardous (classified) locations, electrically powered vacuum cleaners shall be listed for both flammable vapors or gases and combustible dust hazardous (classified) locations.

8.4.2.2.2 Centralized Vacuum Cleaning Systems. A centralized vacuum cleaning system remotely installed beyond the hazardous (classified) location in conformance with Section 9.4 shall be permitted to be used for vacuuming in combustible dust hazardous (classified) locations and where flammable vapors or gases are present in combustible dust hazardous (classified) locations.

8.4.2.3* Sweeping, Shoveling, Scoop, and Brush Cleaning Method. The use of scoops, brooms, and brushes for sweeping and shoveling shall be subject to the requirements of the industry- or commodity-specific chapters.

8.4.2.4* Water Washdown Cleaning Method.

8.4.2.4.1 The use of water washdown shall be a permitted cleaning method subject to the requirements of the industry- or commodity-specific chapters.

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

8.4.2.5 Water Foam Washdown Systems. (Reserved)

8.4.2.6 Compressed Air Blowdown Method.

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.

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, brushing, sweeping, or water washdown methods are used to clean surfaces that can be safely accessed.
- (2) Dust accumulations in the area after vacuum cleaning, brushing, sweeping, or water washdown do not exceed the threshold housekeeping dust accumulation limit.
- (3)* Compressed air hoses are equipped with pressure relief nozzles limiting the discharge pressure to 30 psi (207 kPa).
- (4)* All electrical equipment, including lighting, potentially exposed to airborne dust in the area during cleaning is rated appropriately for dust 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 is not excluded by the criteria of 22.1.1.6.2, the requirements of Chapter 22 apply.
- (8) All fire protection equipment is in service.

8.4.2.7 Steam Blow Down Method. (Reserved)

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

8.4.4 Equipment. (Reserved)

8.4.5 Vacuum Trucks. This section shall apply where the DHA has determined a fire, flash fire, or explosion hazard exists.

8.4.5.1* Vacuum trucks shall be grounded and bonded.

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

8.4.5.3 Vacuum trucks shall be empty and clean prior to arrival on site.

8.4.6 Frequency and Goal.

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

8.4.6.2 The threshold housekeeping dust accumulation limit shall be in accordance with the industry- or commodity-specific chapters in this standard. (*See 1.3.2.*)

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

8.4.7 Auditing and Documentation.

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

8.4.7.2 Where the facility is intended to be operated with less than the dust accumulation in conformance with 8.4.6.1, a planned inspection process shall be implemented to evaluate dust accumulation rates and the housekeeping frequency required to maintain dust accumulations below the threshold dust mass/accumulation.

8.4.7.3 Corrective actions for identified issues from the housekeeping program shall be tracked to ensure completion.

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

8.5 Hot Work.

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 8.5.6.

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

8.5.3 The area affected by the work shall be free from visible airborne combustible dust.

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

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

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

8.5.7 Use of Portable Equipment. Use of portable electrical equipment that does not comply with the electrical classifica-

tion 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.

8.5.8* Propellant-Actuated Devices and Explosive-Actuated Devices.

8.5.8.1 Propellant-actuated devices and explosive-actuated devices shall not be used in areas where combustible dust or dust clouds are present.

8.5.8.2 When the use of propellant-actuated devices or explosive-actuated devices becomes necessary, the area shall be prepared in accordance with 8.5.1 through 8.5.6.

8.5.8.3 A check shall be made after the work is completed to ensure that no cartridges or charges are left in the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or dust-handling machinery is resumed.

8.6 Personal Protective Equipment (PPE).

8.6.1* PPE Applicability.

8.6.1.1 Flame-resistant garments designed in accordance with NFPA 2112 shall be permitted to be used as part of the personnel protection strategy against localized flash fire exposures, only.

8.6.1.2* Flame-resistant garments shall not be permitted to be the sole safeguard against a propagating deflagration through suspended dust accumulations throughout a building compartment.

8.6.2 Workplace Hazard Assessment.

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

8.6.2.2 When the assessment in 8.6.2.1 has determined that flame-resistant garments are needed, personnel shall be provided with and wear flame-resistant garments.

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

8.6.2.4 In addition to flame-resistant garments complying with NFPA 2112, the organization shall consider factors in selecting flame-resistant garments including, but not limited to, the following:

- (1)* Thermal protective characteristics of the fabric and materials over a range of thermal exposures (e.g., to evaluate the effect of delayed egress)
- (2)* Physical characteristics of the fabric and materials
- (3)* Garment construction and components (e.g., pockets, types of closures)
- (4)* Avoidance of static charge buildup
- (5)* Design type of the garment
- (6)* Type of conditions under which the garments will be worn
- (7)* Comfort properties of the fabric, materials, and garment
- (8)* Cleaning and maintenance considerations

[2113:4.3.1]

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

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

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

8.6.3.1* When flame-resistant garments are required by 8.6.2.1, flame-resistant or nonmelting undergarments shall be used in accordance with NFPA 2113.

8.6.3.2* When determined by 8.6.2.1 that flame-resistant garments are needed, only flame-resistant outerwear shall be worn over flame-resistant garments.

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

8.6.5 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, flash fires, and explosions shall be inspected, tested, and maintained in accordance with one of the following:

- (1) The applicable NFPA standard and the manufacturers' recommendations
- (2) Where there is no applicable NFPA standard, the manufacturers' recommendations as modified by operational experience

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 equipment
- (4)* Potential ignition sources
- (5) Electrical, process, and mechanical equipment
- (6)* Instrumentation, including process interlocks
- (7) Lubrication of bearings
- (8)* Tramp metal detection and removal devices

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, flash fires, and explosions.

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

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

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.

8.7.7 A qualified person shall conduct inspection and testing, then document the findings and recommendations.

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, to include the following elements:

- (1) The hazards present in the working environment
- (2) Emergency response plans, including evacuation routes
- (3) Site safety rules

8.8.2.1* Job-specific training shall ensure that employees are knowledgeable about fire, flash fire, and explosion hazards of combustible dusts and particulate solids in their work environment, including the following elements as applicable:

- (1) Hazards specific to the work area and equipment, including hazards associated with fire and explosion suppression equipment
- (2) Equipment operation procedures, including safe start-up/shutdown, response to upset conditions, and emergency shutdown
- (3) Inspection, testing, and maintenance procedures
- (4) The necessity for proper functioning of related fire and explosion protection systems
- (5) Procedures in response to emergencies, including emergency notification and permissible methods for fighting incipient fires in the work area
- (6) The location and operation of fire protection equipment, manual pull stations and alarms, emergency phones, first-aid supplies, and safety equipment
- (7) Safe handling, use, storage, and disposal of hazardous materials
- (8) Housekeeping requirements including proper cleaning methods
- (9) Personal protective equipment requirements and proper use
- (10) Reporting of incidents

8.8.2.2 Employees shall be trained before taking on job-related responsibilities.

8.8.2.3* Where explosion protection systems or emergency shutdown 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 at least every three years after initial training or as required by the applicable industry- or commodity-specific chapters of this standard, whichever is shorter.

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, flash 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* The training provided to contractors shall be equivalent to the training that would be provided to employees who could operate the same equipment.

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, flash 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 8.3.4.

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.

8.9.3.6 Contractors shall receive refresher training annually.

8.9.3.7 Contractor training shall be documented.

8.10* Incident Investigation.

8.10.1 The owner/operator shall have a system to ensure that incidents that result in a fire, flash fire, or explosion are reported and investigated.

8.10.2* Events that could have resulted in fires, flash fires, or explosions under different circumstances but where property losses or injuries were not experienced shall be investigated.

8.10.3 Once the scene has been released to the owner/operator, incident investigations shall be promptly initiated by management personnel or by a designee who has a working knowledge of the facility and processes.

8.10.4* A written report of the investigation shall be prepared that describes the incident, lists what has been learned from the investigation, and makes recommendations to prevent reoccurrence of that or similar incidents.

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

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

8.11* Management of Change.

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

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

- (1)* The technical basis for the proposed change
- (2)* Safety and health implications
- (3) Whether the change is permanent or temporary, including the authorized duration of temporary changes
- (4) Modifications to operating, maintenance, and emergency response 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) Implementation of any recommendations required for safe operation of the change before startup
- (9) Confirmation that the change has been implemented per design prior to startup

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

8.11.4* Process and technology documentation shall be updated to incorporate the change.

8.12* Operational Readiness Review (ORR).

8.12.1* The owner/operator shall perform an operational readiness review before the start-up of the following:

- (1) New facilities
- (2) Modified facilities when the modification is significant enough to require change in the process and technology information required by 8.13.1(5)
- (3) Facilities that have been shut down for minor maintenance activities
- (4) Facilities that are periodically shut down as part of normal operations
- (5)* Facilities that have been shut down for extended periods of time

8.12.2* The scope and detail of the operational readiness review shall consider the nature and duration of the shutdown and shall confirm the following prior to start-up of the facility:

- (1) For new facilities:
 - (a) Construction and equipment are in accordance with design specifications.
 - (b) A DHA has been performed in conformance with Chapter 7, and action items have been resolved or implemented before startup.
 - (c) Accurate, up-to-date safety, operating (including startup), maintenance, and emergency procedures are in place.
 - (d) Affected personnel have been trained on relevant procedures.
 - (e) Inspection and testing of safety systems and equipment have been conducted.
- (2) For modified facilities:
 - (a) A management of change review has been conducted in conformance with Section 8.11, and action items have been resolved or implemented before startup.
 - (b) Construction and equipment are in accordance with design specifications.
 - (c) Accurate, up-to-date safety, operating (including startup), maintenance, and emergency procedures are in place.
 - (d) Affected personnel have been trained on relevant procedures.
 - (e) Inspection and testing of safety systems and equipment have been conducted.
- (3) For facilities that have been shut down for minor maintenance:
 - (a) Construction and equipment are in accordance with design specifications.

- (b) A joint inspection by maintenance and operations personnel has verified that the maintenance has been correctly completed.
- (c) Accurate, up-to-date startup procedures are in place.
- (4) For facilities that have been shut down as part of normal operations:
 - (a) A walk-through inspection has verified that the facility is ready for start-up.
 - (b) Accurate, up-to-date startup procedures are in place.
- (5) For facilities that have been shut down for extended periods of time:
 - (a) A DHA has been performed or updated in conformance with Chapter 7, and action items have been resolved or implemented before startup.
 - (b) Construction and equipment are in accordance with design specifications.
 - (c) Accurate, up-to-date safety, operating (including startup), maintenance, and emergency procedures are in place.
 - (d) Affected personnel have been trained on relevant procedures.
 - (e) Inspection and testing of safety systems and equipment have been conducted.

8.12.3* The operational readiness review shall be documented and the documentation retained in conformance with 8.13.1(7).

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 and resolution of DHA recommendations
- (5)* Process and technology information
- (6)* Management of change documents
- (7) Operational readiness review documents for start-up associated with 8.12.2(1), 8.12.2(2), and 8.12.2(5).
- (8) Emergency response plan documents
- (9)* Contractor records

8.14 Management Systems Review.

8.14.1 The owner/operator shall be responsible for maintaining and evaluating the ongoing effectiveness of the management systems required by this standard.

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

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. (Reserved)

9.2 Risk Assessment.

9.2.1* A documented risk assessment shall be permitted to determine the required protections in Chapter 9.

9.2.2 Upon request, the AHJ shall be provided with sufficient documentation to support the validity and relevance of the risk assessment methodology permitted in Chapter 9.

9.3 Building Design.

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

9.3.2 Building or Building Compartment Protection.

9.3.2.1* Each building or building compartment where a dust or particulate solid fire, flash fire, or explosion hazard exists shall be protected from the consequence of fire, flash fire, or explosion.

9.3.2.2* 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.

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

9.3.2.2.2* The fireball, blast hazards, and missile hazards that are created by deflagration venting shall not expose personnel or property assets outside of the compartment being protected.

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

9.3.3.1 Where a dust or particulate solid fire, flash fire, or explosion 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.

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

9.3.4 Construction Features to Limit Accumulation.

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

9.3.4.2* Building spaces inaccessible to routine housekeeping shall be sealed to prevent dust accumulation.

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

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

9.3.5.1 General. Areas where a dust or particulate solid fire, flash fire, or explosion hazard exists in a building or building

compartment (excluding hazards within equipment) shall be segregated, separated, or detached from other occupancies to minimize damage from a fire, flash fire, or explosion.

9.3.5.2 Use of Segregation.

9.3.5.2.1 Where physical barriers are erected for the purpose of limiting fire spread, they shall be designed in accordance with NFPA 221 or the building code adopted by the AHJ.

9.3.5.2.2 Physical barriers erected to segregate fire hazard areas, including seals at all penetrations and openings of floors, walls, ceilings, or partitions, shall have a minimum fire resistance rating based on the fire duration stated in the applicable fire code.

9.3.5.2.3 Where physical barriers, including all penetrations and openings of floors, walls, ceilings, or partitions, are erected to segregate dust explosion hazard areas, they shall be designed in accordance with NFPA 68 to preclude failure of those barriers during a dust explosion.

9.3.5.2.4 Where physical barriers, including floors, walls, ceilings, or partitions, are erected to prevent the migration of dust, all penetrations and openings shall be sealed.

9.3.5.3 Use of Separation.

9.3.5.3.1* Separation shall be permitted to be used to limit the dust or particulate solid fire, flash fire, or explosion hazard areas within a building when it is supported by a documented evaluation.

9.3.5.3.2* The required separation distance between the dust or particulate solid fire, flash fire, or explosion 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, including during abnormal or transient operations
- (4) Building and equipment design
- (5) Nature of surrounding exposures

9.3.5.3.3* Where separation is used to limit the dust or particulate solid fire, flash fire, or explosion hazard area determined in Chapter 7, the minimum separation distance shall not be less than 35 ft (11 m).

9.3.5.3.4 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.

9.3.5.3.5 Housekeeping shall be promptly undertaken if the color of the underlying surface is not discernible.

9.3.5.3.6* 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 or particulate solid fire, flash fire, or explosion hazard area.

9.3.5.4 Use of Detachment.

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

9.3.5.4.2* The required detachment distance between the dust flash fire or explosion hazard area and surrounding exposures shall be determined by a documented 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, including during abnormal or transient operations
- (4) Building and equipment design
- (5) Nature of surrounding exposures

9.4 Equipment Design.

9.4.1 General.

9.4.1.1* 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.

9.4.1.2* Where it is necessary to make changes to existing equipment or systems, all changes shall be managed in accordance with the management of change requirements in Section 8.11.

9.4.2 Design for Dust Containment.

9.4.2.1 All components of enclosed systems that handle combustible particulate solids shall be designed to contain the dust to prevent creation of fugitive combustible dust hazards external to the equipment.

9.4.2.2* Where the equipment cannot be designed to prevent the escape of dust from the intended process zone, dust control shall be provided. (*See also 9.4.3.*)

9.4.2.3 Openings provided specifically for inspection or necessary process intake or discharge shall be permitted, provided they too do not permit fugitive dust release.

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

9.4.3.1 General Requirements.

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

9.4.3.1.2* Equipment controlling the operation of the system shall be installed in a location where the operator is safe from the pressure and thermal effects of an explosion in the system.

9.4.3.1.3 Systems That Convey Hybrid Mixtures. Where the combined percentage of the lower flammable limit (LFL) of flammable vapors and the percentage of the minimum explosible concentration (MEC) of combustible dusts exceeds 25 percent within the airstream, protection shall be provided in accordance with 9.8.2.2(1) through 9.8.2.2(6).

9.4.3.1.4* Operations.

9.4.3.1.4.1 Sequence of Operation. Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall be designed with the operating logic, sequencing, and timing outlined in 9.4.3.1.4.2 and 9.4.3.1.4.3.

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

9.4.3.1.4.3 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 9.4.3.1.4.3(A) shall not apply during emergency shutdown of the process, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

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

9.4.3.1.5 Airflow Control Valves.

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

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

9.4.3.1.5.3 The position of airflow control valves shall be visually or electronically indicated.

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

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

9.4.3.2* Specific Requirements for Pneumatic Conveying Systems.

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

9.4.3.2.2* 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 components exposed to that pressure under normal or upset conditions shall be designed in accordance with the applicable pressure vessel or process piping code.

9.4.3.2.3* Pneumatic conveying systems conveying combustible particulate solids and posing an explosion hazard shall be protected in accordance with Section 9.8.

9.4.3.3* Specific Requirements for Dust Collection Systems.

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

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

9.4.3.3.3* 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.

9.4.3.3.4* 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.

9.4.3.3.5* Dust collection systems that remove material from operations that could generate flames, sparks, or hot material under normal operating conditions shall provide a means to prevent propagation of these flames, sparks, or hot materials to the AMS or creation of a fire or explosion hazard within the ductwork.

9.4.3.3.6* The AMS selected for the system shall be designed to allow for the characteristics of the combustible dust being separated from the airflow or gas flow.

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

9.4.3.3.8* Heating, ventilation, and air conditioning (HVAC) systems shall not be used as the means to collect dusts from localized sources.

9.4.3.4* Specific Requirements for Centralized Vacuum Cleaning Systems.

9.4.3.4.1* 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.

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

9.4.3.4.3 The system shall be operated only with the hoses and tools that have been designated in the design documentation for the specific hose connection station.

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

9.4.3.4.5* Vacuum cleaning hose shall be static dissipative or conductive and bonded to the central vacuum system.

9.4.4 AMS.

9.4.4.1 General.

9.4.4.1.1 The discharge conveying system shall be designed to handle the maximum material flow separated from the air stream.

9.4.4.1.2* Controls shall be provided to prevent accumulation in the AMS that could interfere with the operation of the AMS or associated explosion protection systems.

9.4.4.2* Dry AMS. Where an explosion hazard exists, AMSs with a dirty side volume of the air-material separator is greater than 8 ft³ (0.2 m³), or greater shall be protected in accordance with Section 9.8.

9.4.4.3 Wet AMS. See 9.4.4.5.3.

9.4.4.4 Enclosureless AMS. See 9.4.4.5.4.

9.4.4.5 AMS Locations.

9.4.4.5.1 Where an explosion hazard exists, AMSs with a dirty-side volume of 8 ft³ (0.2 m³) or greater shall be located outside of buildings.

9.4.4.5.2 The requirement of 9.4.4.5.1 shall not apply to the following:

- (1) AMSs that are protected in accordance with 9.8.2
- (2) AMSs that are allowed by an industry- or commodity-specific chapter

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

- (1) A means is provided to prevent startup or continued operation if the flow rate of the scrubbing medium is less than the designed minimum flow rate.
- (2) The scrubbing medium is not an ignitable (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.

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

9.4.4.6 AMS Clean Air Exhaust.

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

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

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

- (1) 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.
- (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 risk assessment 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 risk assessment 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 housekeeping requirements of 8.4.6.

- (8) Recycled-air ducts are inspected at least annually and cleaned if dust accumulations are present.

9.4.4.6.4 Recycling of AMS exhaust to buildings or building compartments shall be permitted for enclosureless AMS as permitted by 9.4.4.5.4 and the industry- or commodity-specific chapter of this standard.

9.4.4.7 AMS Construction.

9.4.4.7.1 AMSs shall be constructed of noncombustible materials.

9.4.4.7.2 Filter media and filter media support frames shall be permitted to be constructed of combustible material.

9.4.4.7.3 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.

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

9.4.4.7.5* AMS units with angled bottom construction shall use a slope that is sufficient to promote material flow to the discharge.

9.4.4.7.6* AMS units with flat bottom construction shall be provided with a positive method to direct collected material to the discharge.

9.4.4.7.7 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.

9.4.5 Air-Moving Devices (Fans and Blowers).

9.4.5.1 AMDs shall conform to the requirements of NFPA 91, except as amended by the requirements of this chapter.

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

9.4.5.3* The requirement of 9.4.5.2 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 9.8.2.2(1), 9.8.2.2(5), 9.8.2.2(6), or 9.8.3.

9.4.5.4* 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 Standard 99, *Standards Handbook*, or Type C spark-resistant construction protected with spark detection and extinguishment located downstream of the fan.

9.4.6 Duct Systems.

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

9.4.6.2* 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.

9.4.6.3* When ducts pass through a physical barrier erected to segregate dust or particulate solid fire, flash fire, or explosion hazards, physical isolation protection shall be provided to prevent propagation of fire, flash fire, or explosions between segregated spaces.

9.4.6.4 Access Doors.

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

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

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

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

9.4.7* Sight Glasses.

9.4.7.1 Sight glasses shall be of a material that is impact- and erosion-resistant.

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

9.4.7.3 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.

9.4.7.4 The mechanical strength of the sight glass-mounting mechanism shall be equal to the adjoining ductwork.

9.4.7.5 The inside diameter of a sight glass shall not cause a restriction of flow.

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

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

9.4.8 Abort Gates.

9.4.8.1 Construction.

9.4.8.1.1 Abort gates shall be constructed of noncombustible materials.

9.4.8.1.2 Abort gates shall be actuated by spark detection or equivalent automatic detection in the duct or pipe upstream of the device.

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

9.4.8.1.4 The abort gate shall be installed so that it diverts airflow to an access-restricted area to safely discharge combustion gases, flames, burning solids, or process gases or fumes.

9.4.8.2 Local Reset.

9.4.8.2.1 An abort gate shall be provided with a reset located proximate to the device.

9.4.8.2.2 Automatic or remote reset provisions shall not be permitted.

9.4.8.3 Integrity of Actuation Circuits.

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

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

9.4.9 Bulk Storage Enclosures.

9.4.9.1 General.

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

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

9.4.9.2* Construction. Where bulk storage enclosures, whether located inside or outside of buildings, are built of materials that could contribute to the fire load, the design of fire protection shall take that into consideration.

9.4.9.3 Fixed Bulk Storage Location.

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

9.4.9.3.2 Fixed bulk storage enclosures with explosion hazards shall be permitted to be located inside buildings where one of the following applies:

- (1) Fixed bulk storage enclosures are protected in accordance with 9.8.2.
- (2)* Fixed bulk storage enclosures are less than 8 ft³ (0.2 m³).

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

9.4.9.5 Access Doors and 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.

9.4.10* Size Reduction. Where a fire or explosion hazard would otherwise result, before material is processed by size reduction equipment, foreign materials shall be excluded or removed as required by 9.6.11.

9.4.11* Particle Size Separation.

9.4.11.1 Particle separation devices shall be designed to control fugitive dust emissions per Section 9.5.

9.4.11.2 Flexible connectors shall be in conformance with 9.6.6.1.4.

9.4.12 Pressure Protection Systems.

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

9.4.12.2 Pressure Relief Devices.

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

9.4.12.2.2 The requirement of 9.4.12.2.1 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*.

9.4.12.2.3 The requirement of 9.4.12.2.1 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.

9.4.12.2.4* Pressure relief devices shall not be vented to an area where a dust or particulate solid fire, flash fire, or explosion hazard exists in accordance with 7.3.4.

9.4.13 Mechanical Feeding Devices. For requirements on mechanical feeding devices, see industry- or commodity-specific chapters.

9.4.14 Bucket Elevators. For requirements on bucket elevators, see industry- or commodity-specific chapters.

9.4.15 Conveyors and Spouts. For requirements on conveyors, see industry- or commodity-specific chapters.

9.4.16 Mixers and Blenders. For requirements on mixers and blenders, see industry- or commodity-specific chapters.

9.4.17* Dryers.

9.4.17.1 Drying Media.

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

9.4.17.1.1.1* Recycling of exhaust from a dryer system to buildings or building compartments shall be permitted when all the following conditions are met:

- (1) 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 LFL, whichever is lower.
- (2)* Combustible particulate solids are not present in the recycled air in concentrations above applicable industrial hygiene exposure limits.
- (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 a dryer system back to the facility unless a risk assessment 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 a dryer system back to the

facility unless a risk assessment indicates that those effects do not pose a threat to the facility or the occupants.

- (6) The system includes a method for detecting and mitigating dryer system malfunctions that would 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 housekeeping requirements of 8.4.6.
- (8) Recycled-air ducts are inspected at least annually and cleaned if dust accumulations are present.

9.4.17.1.2* Where a combustible dust hazard exists in the dryer or recycled air stream during the drying process, those hazards shall be controlled.

9.4.17.1.3 Dryers shall be constructed of noncombustible materials.

9.4.17.1.4 Interior surfaces of dryers shall be designed to minimize combustible material accumulations and facilitate cleaning.

9.4.17.1.4.1* Dryer cleaning methods, frequency, and the required level of cleanliness shall be documented.

9.4.17.1.5 Access doors or openings shall be provided in the dryer system and connected conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams.

9.4.17.1.6 Heated dryers shall comply with NFPA 86.

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

9.4.17.1.8* Heated dryers and their auxiliary equipment shall be equipped with an excess-temperature-limit safety interlock, 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

9.4.18 Transfer Points. (Reserved)

9.5 Dust Control.

9.5.1 General.

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

9.5.1.2 Where continuous suction is used, the dust shall be conveyed to air-material separators designed in accordance with 9.4.3.

9.5.2* Liquid Dust Suppression Methods for Dust Control.

9.5.2.1 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.

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

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

9.5.3.1 Fans shall be appropriate for the electrical classification in the areas where they are used.

9.5.3.2 Fans shall be provided in sufficient numbers and locations as required to keep the target areas below threshold accumulation levels.

9.5.3.3 Fans shall be in operation whenever the equipment generating the dusts is in operation.

9.5.3.4 Fans shall be interlocked to automatically shut down in the event of automatic fire suppression system operation.

9.5.3.5 Dust dispersed by the fans shall not create an explosive dust cloud.

9.5.3.6 The location and range of motion of the fans shall be designed to prevent flow impingement on open equipment containing entrainable dust.

9.5.3.7 Areas that will be swept by the fans shall be below threshold accumulation levels prior to placing or returning the fans in operation.

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

9.5.3.9 These systems shall not be used where they can relocate dust into unsealed concealed spaces where the dust can accumulate and pose a fire, flash fire, or explosion hazard.

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

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

9.6 Ignition Source Control.

9.6.1* Retroactivity. Unless otherwise specified, the requirements of Section 9.6 shall be applied retroactively.

9.6.2 Hot Work. See Section 8.5.

9.6.3 Hot Surfaces.

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

9.6.3.2* In areas where a dust explosion hazard or dust flash fire hazard exists, the temperature of exposed surfaces shall be maintained below 80 percent (in degrees Celsius) of the lower of the dust layer ignition temperature or the dust-cloud ignition temperature.

9.6.4 Bearings.

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

9.6.4.2* 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.

9.6.4.3 The owner/operator shall establish frequencies for monitoring bearings in 9.6.4.2.

9.6.4.4* It shall be permitted to eliminate bearing monitoring based on a risk assessment in accordance with Section 9.2.

9.6.5 Hazardous (Classified) Locations for Electrical Installations.

9.6.5.1* The identification of the possible presence and extent of hazardous (classified) locations shall be made based on the criteria in Articles 500 and 506 of *NFPA 70*.

9.6.5.1.1* The locations and extent of hazardous (classified) locations shall be documented, and such documentation shall be preserved for access at the facility.

9.6.5.2 Electrical equipment and wiring within hazardous (classified) locations shall comply with *NFPA 70*.

9.6.5.3* Preventive maintenance programs for electrical equipment and wiring in hazardous (classified) locations shall include provisions to verify that dusttight electrical enclosures are not experiencing visible dust accumulation.

9.6.5.4* Electrical equipment exposed to a process-specific oxidizing medium, other than air, shall only use dust exclusion protection methods unless supported by a documented risk assessment.

9.6.6* Electrostatic Discharges.

9.6.6.1 Conductive Equipment.

9.6.6.1.1 Particulate handling equipment shall be conductive unless the provisions of 9.6.6.1.2 are applicable.

9.6.6.1.2 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, membranes, or pipe/vessel wall with thickness less than 0.3 in. (8 mm) does not exceed 4 kV, and the breakdown strength across nonconductive woven materials does not exceed 6 kV, when used in high surface charging processes.

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

9.6.6.1.4* Flexible Connectors.

9.6.6.1.4.1* This section shall not be required to be applied retroactively.

9.6.6.1.4.2* Flexible connectors used for pneumatic conveying, dust collection, or vacuum cleaning, regardless of length, shall have an end-to-end resistance of less than 1.0×10^6 ohms even where an internal or external bonding wire connects the equipment to which the flexible connector is attached.

9.6.6.1.4.3* Flexible connectors used for gravity or mechanical conveying, regardless of length, shall have an end-to-end resistance of less than 1.0×10^8 ohms even where an internal or

external bonding wire connects the equipment to which the flexible connector is attached.

9.6.6.1.4.4* 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 ft/min (10 m/sec).

9.6.6.2* Maximum Particulate Transport Rates. For requirements on this subject, see industry- or commodity-specific chapters.

9.6.6.3* Grounding of Personnel.

9.6.6.3.1* Where an explosible 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.

9.6.6.3.2 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.

9.6.6.4* 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 9.6.6.4.1 through 9.6.6.4.7.

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

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

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

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

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

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

9.6.6.4.3.2 Type B FIBCs shall not be used for conductive dusts. (See A.9.6.6.4.2.2.)

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

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

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

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

9.6.6.4.5* Type D FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I 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.

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

9.6.6.4.6* 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.

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

9.6.6.4.6.2 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.

9.6.6.4.6.3* Where used, inner liners shall be suitable to maintain the electrostatic characteristics of the bag types in which they are used.

9.6.6.4.6.4 Documentation of test results shall be made available upon request of the AHJ.

9.6.6.4.6.5 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.

9.6.6.4.7* Deviations from the requirements in 9.6.6.4.1 through 9.6.6.4.6 for safe use of FIBCs shall be permitted based on a documented risk assessment in accordance with Section 9.2.

9.6.6.5 Rigid Intermediate Bulk Containers (RIBCs).

9.6.6.5.1* 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.

9.6.6.5.2* 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 of the electrostatic hazards is completed in accordance with Section 9.2.

9.6.7 Open Flames and Fuel-Fired Equipment.

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

9.6.7.2 Fuel-fired space heaters drawing local ambient air shall not be located within hazardous (classified) locations.

9.6.7.3 Fuel-fired process equipment shall be operated and maintained in accordance with the pertinent NFPA standard for the equipment, including NFPA 31, NFPA 54, NFPA 85, and NFPA 86.

9.6.7.4 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.

9.6.7.5 Unless the equipment is operated within the limits of 9.6.3.2, provisions shall be made to prevent the accumulation of combustible dust on heated surfaces of heating units.

9.6.7.6 In facility locations that have been identified as being dust flash fire or explosion hazard areas or hazardous (classified) locations, heating units shall be provided with a source of combustion air ducted directly from the building exterior or from an unclassified location.

9.6.8 Industrial Trucks.

9.6.8.1 Industrial trucks shall be listed or approved for the electrical classification of the area, as determined by 9.6.5, and shall be used in accordance with NFPA 505.

9.6.8.2* Where industrial trucks in accordance with NFPA 505 are not commercially available, a documented risk assessment in accordance with Section 9.2 shall be permitted to be used to specify the fire and explosion prevention features for the equipment being used.

9.6.9 Process Air and Media Temperatures.

9.6.9.1* Heated process equipment containing combustible dust shall have operating controls arranged to maintain the temperature of equipment interiors within the prescribed limits as documented by the DHA.

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

9.6.10.1 Material that has self-heating characteristics shall be managed or stored to control self-heating or have self-heating detection provisions.

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

9.6.11 Friction and Impact Sparks.

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

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

9.6.11.3* Where introduction of tramp materials cannot be prevented, explosion protection shall be provided for all equipment subject to the explosion hazard.

9.6.11.4* Clearances and alignment of high-speed moving parts in equipment that is processing combustible particulates

shall be managed according to the occupancy-specific chapters where required to prevent creation of ignition sources.

9.6.12* Lightning Protection. Lightning protection, where provided, shall be designed, installed, and maintained in accordance with NFPA 780.

9.6.13* Smoking and Vaping. Where smoking and vaping is permitted in the facility, it shall be restricted to designated nonhazardous areas equipped with devices for smoking material disposal and free of combustible/flammable hazards or storage.

9.7 Pyrophoric Dusts. (Reserved)

9.8 Explosion Prevention and Protection.

9.8.1 General. Where a dust explosion hazard exists within an enclosure, measures shall be taken as specified in Section 9.8 to protect personnel from the consequences of an explosion in that enclosure.

9.8.2 Equipment Protection.

9.8.2.1* Where an explosion hazard exists within any operating equipment greater than 8 ft³ (0.2 m³) of containing volume, the equipment shall be protected from the effects of an explosion.

9.8.2.2* 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

9.8.2.3 Enclosures and all interconnections protected in accordance with 9.8.2.2 shall be designed to withstand the resultant pressures produced during the deflagration event.

9.8.2.4 Where both an explosion hazard and a fire hazard exist in an AMS, protection for each type of hazard shall be provided.

9.8.3* Equipment Isolation.

9.8.3.1 Where a dust explosion hazard exists, isolation devices shall be provided in accordance with NFPA 69 to prevent propagation of flames and pressure between connected equipment.

9.8.3.2 Isolation devices shall not be required where oxidant concentration has been reduced in accordance with NFPA 69 or where the dust has been rendered noncombustible in accordance with 9.8.2.2(6).

9.8.3.3 Where a dust explosion hazard exists, isolation devices shall be provided in accordance with NFPA 69 to prevent propagation of flames and pressure from equipment through ductwork to the work areas.

9.9 Fire Protection.

9.9.1 General.

9.9.1.1 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 9.9.

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

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

9.9.2 System Requirements. Fire protection systems where provided shall comply with 9.9.2.1 through 9.9.2.4.

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

9.9.2.2 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.

9.9.2.3 Where firefighting water or wet product can accumulate in the system, the vessel, pipe supports, and drains shall be designed to support the additional water weight in accordance with NFPA 91.

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

9.9.3 Fire Extinguishers.

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

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

9.9.4 Hose, Standpipes, Hydrants, and Water Supply.

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

9.9.4.2 Nozzles.

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

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

9.9.4.2.3 It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible with nozzles specified in 9.9.4.2.1.

9.9.4.3 Water Supply.

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

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

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

9.9.5 Automatic Sprinklers.

9.9.5.1* Where a process that handles combustible particulate solids uses ignitable (flammable or combustible) liquids, a documented risk assessment in accordance with Section 9.2 shall be used to determine the need for automatic sprinkler protection in the enclosure in which the process is located.

9.9.5.2* Automatic sprinkler protection shall not be permitted in areas where water-reactive combustible metals or water-reactive materials are produced or handled unless permitted by a risk assessment.

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

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

9.9.6 Detection and Extinguishing Systems.

9.9.6.1 Where provided, spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 15, NFPA 69, and NFPA 72.

9.9.6.2* 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
- (2) NFPA 12
- (3) NFPA 12A
- (4) NFPA 15
- (5) NFPA 17
- (6) NFPA 25
- (7) NFPA 750
- (8) NFPA 2001

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

9.9.6.4 Where fire detection systems are incorporated into the pneumatic conveying, dust collection, or centralized vacuum cleaning system, the fire detection systems shall be interlocked to shut down any active device feeding materials to the pneumatic conveying, dust collection, or centralized vacuum cleaning system, on actuation of the detection system.

9.9.6.5* Where spark or infrared detection and extinguishing systems are provided, the process shall be permitted to continue operating on activation of the detection system.

9.9.6.6* Where a spark or infrared detection system actuates a diverter valve or abort gate that sends potentially burning material to a safe location, the process shall be permitted to continue operating on activation of the detection system.

9.9.6.7 Where the actuation of fire-extinguishing systems is achieved by means of electronic fire detection, the fire detection system, including control panels, detectors, and notification appliances, shall be designed, installed, and maintained in accordance with NFPA 72.

9.9.6.7.1 All fire detection initiating devices shall be connected to the fire detection control panel via Class A or Class B circuits as described in NFPA 72.

9.9.6.7.2 All fire detection notification appliances shall be connected to the fire detection control panel via Class A or Class B circuits as described in NFPA 72.

9.9.6.7.3 All fire-extinguishing system releasing devices, solenoids, or actuators shall be connected to the fire detection control panel via Class A or Class B circuits as described in NFPA 72.

9.9.6.7.4 The supervision in 9.9.6.7.3 shall include the continuity of the extinguishing system releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device.

9.9.6.7.5 All supervisory devices that monitor critical elements or functions in the fire detection and extinguishing system shall be connected to the fire detection control panel via Class A or Class B circuits as described in NFPA 72.

9.9.7 Fire Alarm Service. Fire alarm service, if provided, shall comply with NFPA 72.

Chapter 10 Emergency Planning and Response

10.1 Retroactivity. This chapter and the corresponding X.10 sections of the industry- and commodity-specific chapters shall be applied retroactively to new and existing facilities and processes.

10.2 Emergency Response Plan.

10.2.1* A written emergency response plan shall be developed for preparing for and responding to work-related emergencies including, but not limited to, fires, flash fires, and explosions.

10.2.1.1 The emergency response plan shall be available on-site or electronically.

10.2.1.2 The emergency response plan shall include, but not be limited to, the following:

- (1)* A means of notification for occupants in the event of fire and explosion
- (2) A preplanned evacuation assembly area
- (3) A person(s) designated to notify emergency responders, including the fire department
- (4) A facility layout drawing(s) showing egress routes, hazardous chemical locations, and fire protection equipment
- (5) Location of a safety data sheet(s) for hazardous chemicals
- (6) An emergency telephone number(s)
- (7) Emergency response duties for occupants
- (8) A person(s) designated to meet the offsite emergency responder(s) to coordinate the incident

10.2.2 The emergency response plan and procedures shall be reviewed and validated at least annually and as required by process changes.

10.2.3 The emergency response plan shall be shared with relevant local community officials and emergency response agencies.

10.3 Reserved.**Chapter 11 Reserved****Chapter 12 Reserved****Chapter 13 Reserved****Chapter 14 Reserved****Chapter 15 Reserved****Chapter 16 Reserved****Chapter 17 Reserved****Chapter 18 Reserved****Chapter 19 Reserved****Chapter 20 Reserved**

Chapter 21 Agricultural and Food Processing

21.1 Administration.

21.1.1 Scope. This chapter provides requirements applicable to agricultural and/or food processing facilities for managing or mitigating fire and explosion hazards of combustible agricultural or food processing dusts or related particulate solids.

21.1.2 Purpose. (Reserved)

21.1.3 Application.

21.1.3.1* This chapter shall apply to all of the following:

- (1) All facilities that receive, handle, process, dry, blend, use, mill, package, store, or ship dry agricultural bulk materials, their by-products, or dusts that include grains, oilseeds, agricultural seeds, legumes, sugar, flour, spices, feeds, dry dairy/food powders, and other related materials
- (2) All facilities designed for manufacturing and handling starch, including drying, grinding, conveying, processing, packaging, and storing dry or modified starch, and dry products and dusts generated from these processes
- (3) Those seed preparation and meal-handling systems of oilseed processing plants not covered by NFPA 36

21.1.3.2 This chapter shall modify and augment the requirements of Chapters 1 through 10.

21.1.3.3 This chapter shall not apply to oilseed extraction processes that are covered by NFPA 36.

21.1.4 Reserved.

21.1.5 Equivalency. (Reserved)

21.1.6 Conflicts. The requirements of this chapter shall be applied or construed so as not to create an unreasonable risk to public food safety.

21.2 Reserved.

21.3 Reserved.

21.4 General Requirements.

21.4.1* General. The owner/operator shall be permitted to consider dust generated from bulk raw grain and other organically-derived materials as agricultural combustible dusts unless available data and/or specific testing shows that the dust is not combustible.

21.4.1.1 Where necessary, testing protocols in Chapter 5 shall be used to identify noncombustible dusts or provide specific information on a given uncharacterized dust.

21.4.2* Objectives. Nothing in the objectives shall allow the AHJ to require changes to Good Manufacturing Practices (GMP), sanitation, or Hazard Analysis Critical Control Points (HACCP).

21.5* Hazard Identification. See Chapter 5.

21.6 Reserved.

21.7 Dust Hazards Analysis (DHA).

21.7.1 General Requirements.

21.7.1.1 Retroactivity.

21.7.1.1.1 A DHA shall be completed for all new and existing processes and facility compartments, and those that are undergoing significant modification.

21.7.1.1.2* When performing a DHA on existing processes and facility compartments, special emphasis shall be on house-keeping and on bucket elevators, conveyors, grinding equipment, spray dryer systems, and dust collection systems.

21.7.1.1.3 For the purposes of applying the provisions of 21.7.1.1.1, significant modification shall include modifications that exceed 25 percent of the replacement cost of the equipment system.

21.7.2 Criteria.

21.7.2.1 Reserved.

21.7.2.2 Qualifications.

21.7.2.2.1 The requirement in 21.7.2.2.2 shall be permitted to be used in lieu of those in 7.2.2.

21.7.2.2.2 The DHA shall be performed by one or more people with combined knowledge of the selected DHA methodology, combustible dust hazards, and the process being evaluated.

21.7.2.3 Documentation.

21.7.2.3.1 The requirement in 21.7.2.3.2 shall be permitted to be used in lieu of those in 7.2.3.

21.7.2.3.2 The results of the DHA shall be documented, including any action items requiring change to process, equipment, safety systems, or facilities.

21.7.3* Methodology.

21.7.3.1 General.

21.7.3.1.1 The requirement in 21.7.3.1.2 shall be permitted to be used in lieu of those in 7.3.1.

21.7.3.1.2 The DHA shall include the following:

- (1) Identification and evaluation of the process or facility areas where fire, flash fire, and explosion hazards exist shall be included.
- (2) Where such a hazard exists, identification and evaluation of specific fire and deflagration scenarios shall include the following:
 - (a) Identification of the safeguards that are in place to manage fire, flash fire, and explosion events
 - (b) Recommendation of additional safeguards
- (3) It shall be permitted to use a checklist to complete a DHA on an agricultural combustible dust. (*See Annex H for a sample checklist.*)

21.7.3.2 Reserved.

21.7.3.3 Process Systems. It shall be permitted to omit the requirements in 7.3.3.

21.7.3.4 Building or Building Compartments.

21.7.3.4.1 The requirements in 21.7.3.4.2 and 21.7.3.4.3 shall be permitted to be used in lieu of those listed in 7.3.4.

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

21.7.3.4.3 The housekeeping program shall be evaluated for effectiveness and compliance with 21.8.4 as a part of the DHA.

21.8 Management Systems.

21.8.1 Reserved.

21.8.2 Reserved.

21.8.3 Reserved.

21.8.4 Housekeeping.

21.8.4.1 Reserved.

21.8.4.2 Methodology.**21.8.4.2.1 Procedure.**

21.8.4.2.1.1* The facility shall develop and implement a written housekeeping program that establishes the frequency and method(s) determined best to reduce accumulations of fugitive agricultural dust on ledges, floors, equipment, and other inside exposed surfaces. Unless a greater threshold for housekeeping dust accumulation is prescribed in writing and justified by a documented risk assessment, the threshold housekeeping dust accumulation limit shall be 3.2 mm ($\frac{1}{8}$ in.) over 5 percent of the footprint area.

21.8.4.2.1.2* Dust on floors, structural members, and other surfaces shall be removed concurrently with operations.

21.8.4.2.2 Reserved.

21.8.4.2.3 Reserved.

21.8.4.2.4 Reserved.

21.8.4.2.5 Reserved.

21.8.4.2.6* Compressed Air Blowdown Method. The requirements in 21.8.4.2.6 shall supersede 8.4.2.6.2.

21.8.4.2.6.1 The use of compressed air or other means that cause dust to be suspended in air during removal from ledges, walls, and other surfaces shall be permitted only after all machinery in the area has been shut down and all sources of ignition controlled.

21.8.4.2.6.2 Areas in processing facilities shall be permitted to be cleaned with compressed air, provided that both of the following conditions are met:

- (1) Airborne material will not envelop adjacent operating equipment.
- (2) Prior to blowdown, areas and adjacent equipment are checked to ensure that no ignition sources are present.

21.8.5* Hot Work.

21.8.5.1 Reserved.

21.8.5.2 Reserved.

21.8.5.3 Reserved.

21.8.5.4 Reserved.

21.8.5.5 Reserved.

21.8.5.6 Reserved.

21.8.5.7 Use of Portable Equipment.

21.8.5.7.1* Work activities that could present an ignition source but do not fit the definition of hot work, such as drilling, sawing, or use of hand-operated portable electrical equipment that does not comply with the electrical classification of the area where it is to be used, shall be permitted in accordance with 21.8.5.7.1.1 through 21.8.5.7.1.6.

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

21.8.5.7.1.2 The area affected by the work shall be free from airborne combustible dust.

21.8.5.7.1.3 Equipment that contains combustible dust and is located near the work area shall be protected from the work.

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

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

21.8.5.7.1.6 The work shall be performed on surfaces and equipment not directly handling combustible dusts.

21.8.5.7.2 Spark-producing portable power tools shall not be used where combustible dust is present.

21.8.5.7.3 When the use of spark-producing tools becomes necessary, the following procedures shall be performed:

- (1) All dust-producing machinery in the area shall be shut down.
- (2) The use of spark-producing tools shall be authorized by the use of a hot work permit.

21.8.6* Personal Protective Equipment (PPE). Personal protective equipment shall be selected in accordance with Section 8.6.

21.8.7 Inspection, Testing, and Maintenance.

21.8.7.1* An inspection of the operating area shall take place on an established schedule to help ensure that the equipment is in safe operating condition and that proper work practices are being followed.

21.8.8 Training and Hazard Awareness. Refresher training shall be provided annually.

21.8.9 Reserved.

21.8.10 Reserved.

21.8.11* Management of Change.

21.8.11.1 The requirement in 21.8.11.1.1 shall be permitted to be used in lieu of those listed in 8.11.1.

21.8.11.1.1* A documented program shall be established and implemented to manage proposed changes to process materials, combustible dust handling equipment, facilities, and fire and explosion protection devices that affect dust, fire, or explosion hazards.

21.8.11.1.2 The owner/operator shall require that a qualified person knowledgeable in the fire and deflagration hazards of agricultural or food dust review the proposed changes.

21.8.11.1.3 The qualified person shall consider the impact of the change as required in 21.8.11.2.1 and how the identified risks will be managed.

21.8.11.2 The requirement in 21.8.11.2.1 shall be permitted to be used in lieu of those listed in 8.11.2.

21.8.11.2.1* The documented program shall ensure that the following are addressed prior to the change:

- (1)* The basis for the proposed change
- (2)* Safety and health implications
- (3) Whether the change is temporary or permanent, including the authorized duration of temporary changes
- (4) Employee training requirements
- (5) Authorization requirements for the proposed change
- (6) Results of characterization tests used to assess the hazard, if conducted
- (7) Implementation of any recommendations required for safe operation of the change before startup
- (8) Impact of the change on the modified system or process
- (9) The evaluation of combustible dust hazards

21.8.12* Operational Readiness Review (ORR).

21.8.12.1 The requirement in 21.8.12.2 shall be permitted to be used in lieu of those listed in Section 8.12.

21.8.12.2 The owner/operator shall perform an operational readiness review for new processes and for modification prior to startup.

21.8.13 Reserved.

21.8.14 Reserved.

21.8.15 Reserved.

21.8.16 Warning Signs.

21.8.16.1 Where personnel are exposed to bodily risk from installed fire or explosion prevention systems, such as inert gas systems used to reduce oxygen concentration or explosion suppression systems, equipment and buildings having such systems shall be provided with warning signs.

21.8.16.2 Warning signs shall indicate the potential dangers, shall state adequate precautions, and shall be posted at all entrances to the building or equipment.

21.8.17 Miscellaneous Storage in Grain-Handling Facilities.

21.8.17.1 Sacks, nonessential uninstalled machinery or parts, or other supplies shall not be stored in areas where the only other combustible material is the agricultural commodity that is being stored.

21.8.17.2 Miscellaneous storage shall not impede facility housekeeping or firefighting.

21.9 Hazard Management: Mitigation and Prevention.

21.9.1 Reserved.

21.9.2 Reserved.

21.9.3 Building Design.

21.9.3.1 Construction.

21.9.3.1.1 Electrical wiring and power equipment shall meet all applicable requirements of *NFPA 70*.

21.9.3.1.2 Interior Wall Construction.

21.9.3.1.2.1 Storage areas larger than 5000 ft² (465 m²) and containing packaging, bagging, palletizing, and pelleting equipment shall be cut off from all other areas with fire barrier walls designed for a minimum fire resistance of 2 hours and designed in accordance with Chapter 8 of *NFPA 5000*.

21.9.3.1.2.2 Warehouse areas shall be designed in accordance with *NFPA 5000*.

21.9.3.1.2.3 Necessary openings in fire walls and fire barrier walls shall be kept to a minimum and be as small as practicable. Such openings shall be protected with listed self-closing fire doors, fire shutters, fire dampers, or penetration seals installed in accordance with Chapter 8 of *NFPA 5000*.

(A) Fire doors, fire shutters, fire dampers, and fire penetration seals shall be listed and shall have a fire protection rating complying with *NFPA 101*.

(B) Hold-open devices, if used, shall be listed and shall activate and allow the door to close upon sensing at least one of the following:

- (1) Heat
- (2) Smoke
- (3) Flames
- (4) Products of combustion

21.9.3.2 Building or Building Compartment Protection.

21.9.3.2.1 Masonry shall not be used for the construction of exterior walls or roofs of areas classified as Class II, Group G, Division 1 in *NFPA 70*.

21.9.3.2.1.1* The requirement in 21.9.3.2.1 shall not apply to masonry walls that are designed for explosion resistance to preclude failure of these walls so the explosion pressure can be vented safely to the outside.

21.9.3.2.2 Facilities that are designed for receiving, shipping, handling, and storing of bulk raw agricultural commodities and are located in a separate structure from grain processing or manufacturing areas and their associated raw material, ingredient, production, and finished product bins shall be located and constructed in accordance with the requirements of 21.9.3.2.2.1 through 21.9.3.2.2.4.

21.9.3.2.2.1 Structures housing personnel-intensive areas not directly involved in operations such as, but not limited to, those involved exclusively in administrative or clerical personnel groups, grain inspection and weighing supervision, or operations from control rooms shall be constructed in a location remote from storage silos and headhouse structures as specified in 21.9.3.2.2.2 through 21.9.3.2.2.4.

(A) The requirement in 21.9.3.2.2.1 shall not apply to small control rooms contiguous to specific operations such as railcar and truck discharging or loading or to control rooms such as those used in feed mills for mixing operations.

21.9.3.2.2.2 Structures housing personnel-intensive areas shall not be constructed directly over subterranean tunnels through

which grain-handling equipment or dust control system ductwork passes or over other tunnels that have direct openings into grain-handling areas.

(A) The requirement in 21.9.3.2.2.2 shall not apply to small control room structures contiguous to specific operations such as railcar and truck discharging or loading.

21.9.3.2.2.3 Where reinforced concrete is used in silos and headhouses, the separation distance from personnel-intensive areas shall be at least 100 ft (30 m).

(A) Distances less than 100 ft (30 m) but in no case less than 50 ft (15 m) shall be permitted where any of the following conditions exist:

- (1) The property boundaries or other permanent constraints preclude 100 ft (30 m).
- (2) Structures do not have inside legs
- (3) Structures have inside legs that are equipped with explosion protection equipment in accordance with 21.9.4.14.

21.9.3.2.2.4 Where the headhouse is constructed of structural steel or reinforced concrete framework with lightweight, explosion-relieving wall panels or does not contain inside or unprotected bucket elevators, the separation distance from personnel-intensive areas shall be at least 50 ft (15 m).

(A) Distances less than 50 ft (15 m) shall be permitted if the property boundaries or other permanent constraints preclude 50 ft (15 m), but in no case shall distances less than 30 ft (9 m) be permitted.

21.9.3.2.3 See 21.9.8.1.1.1 for requirements for explosion protection of buildings and building enclosures.

21.9.3.3 Life Safety.

21.9.3.3.1 Means of egress shall be in accordance with NFPA 101.

21.9.3.3.2 Where the horizontal travel distance to the means of egress is less than 50 ft (15 m) in normally unoccupied spaces, a single means of egress shall be permitted.

21.9.3.3.3 Bin decks shall have two means of egress that are remote from each other such that a single fire or explosion event will not likely block both means of egress.

21.9.3.3.3.1 One means of egress shall be required for bin deck areas where travel distance to the means of egress is less than 50 ft (15 m).

21.9.3.4* Construction Features to Limit Accumulation.

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

21.9.3.5.1 Reserved.

21.9.3.5.2 Use of Segregation. Physical barriers erected for the purpose of limiting fire spread shall be designed in accordance with local code.

21.9.3.5.3 Use of Separation. Where separation is used to limit the dust explosion or deflagration hazard area, the minimum separation distance shall not be less than 35 ft (11 m).

21.9.3.6 Marine Towers.

21.9.3.6.1 Marine towers shall be constructed of noncombustible materials.

21.9.3.6.2 Movable marine towers shall be provided with automatic or manually operated brakes.

21.9.3.6.2.1 Movable marine towers shall be provided with automatic or manual rail clamps.

21.9.3.6.2.2 Equipment to monitor wind velocity shall be installed on movable marine towers.

21.9.3.6.2.3 Rail clamps shall operate or be activated when the wind velocity is great enough to cause movement of the tower, even when brakes or gear drives are preventing the rail wheels from turning.

21.9.3.6.3 Movable marine towers shall have provisions for emergency tie-downs.

21.9.3.6.4 Marine vessel loading equipment, such as conveyors, spouts, or drags, shall have safety devices to prevent the equipment from falling if the operating cable(s) breaks.

21.9.4 Equipment Design.

21.9.4.1 Reserved.

21.9.4.2 Reserved.

21.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

21.9.4.3.1* General Requirements.

21.9.4.3.1.1 Bonding and grounding shall be provided for all components, including sight glasses and couplings.

21.9.4.3.1.2 Electrical wiring and power equipment shall meet all applicable requirements of NFPA 70.

21.9.4.3.1.3* Ingredient transport system installations, whose sole function is to transfer clean food ingredients, shall be permitted to be installed without explosion protection inside of a building where all of the following requirements are met:

- (1) The system is a negative or positive pressure pneumatic conveying system.
- (2) The design of the system ensures isolation from the addition of mechanical or electrical energy and process activities, such as cooking or drying, by positive means, such as rotary valves, filters, normally closed valves, or sealed hoppers, from outside events that could trigger an event such as a flash fire or deflagration.
- (3) The system is protected from foreign material contamination, mechanical energy and size reduction activities, electrical sparks and arcs, and other identifiable ignition sources.
- (4) The system is not a bulk raw grain transportation pneumatic system or dust collection system.
- (5) The material being processed has a minimum ignition energy of more than 10 mJ.
- (6) All components of the system are bonded and grounded.

21.9.4.3.1.4 Reserved.

21.9.4.3.1.5 Reserved.

21.9.4.3.1.6 Reserved.

21.9.4.3.1.7 Piping, Valves, and Blowers.

(A) All piping and tubing systems shall be as follows:

- (1) Supported to include the weight of material in a full or choked position

- (2) Airtight and dusttight
- (3) Assembled in such a manner as to provide convenient disassembly for cleaning

(B) Pressure- and vacuum-relief valves shall be located, designed, and set to relieve pressure to protect the system components.

(C) Multiple-direction valves shall be of airtight and dusttight construction and sized to effect a positive diversion of the product with a full cross-sectional open area. Diversion in one direction shall seal all other directions from air, dust, or product leakage.

21.9.4.3.2 Reserved.

21.9.4.3.3 Specific Requirements for Dust Collection Systems.

21.9.4.3.3.1 Manifolding. Dust collection systems for one or more hammer mills or pulverizer mills shall not be manifolded with other types of machinery.

(A) Conveyors, sifters, and hammer mills used for the sizing of oilseed meals and hulls shall be permitted to have a common dust collection system.

21.9.4.3.3.2* Separate Collection Systems. Each department in starch manufacturing and handling shall have a separate dust collection system.

21.9.4.3.3.3* Dust Liberation. Liberation of dust into the ambient air within a shed or structure from open pits or hoppers, such as truck or railcar dump pits, shall be reduced as much as practical by dust control.

21.9.4.3.3.4 Machinery Startup and Shutdown. Dust collection systems shall be in operation before startup of related machinery.

(A) Shutdown of a dust collection system collecting only combustible dusts shall actuate an audible or visual signal that can be either seen or heard by the attendant.

(B) Procedures shall be established, or an automatic sequence provided, to shut down related machinery if the dust collection system shuts down during operations.

21.9.4.3.3.5 Filter Media Dust Collectors.

(A) Filter media dust collectors shall have a monitoring device (such as a differential pressure gauge) to indicate pressure drop across the filter media.

(B) Manufacturer's recommendations and specifications shall be followed concerning actions to be taken based on the indicated pressure drop across the filter media.

(C) Dust collection systems equipped with deflagration venting or explosion suppression systems shall include a method of shutting down the system automatically when a deflagration event occurs within the AMS.

21.9.4.3.3.6 Floor Sweeps. If provided, floor sweeps shall be on a separate, dedicated vacuum or dust collection system, provided the fan is located downstream of the filter.

21.9.4.3.4 Specific Requirements for Centralized Vacuum Cleaning Systems.

21.9.4.3.4.1 Only static-conductive vacuum cleaning tools shall be used and shall be properly grounded to the hose end.

21.9.4.3.4.2 Only static-dissipative hoses shall be used and shall be properly grounded.

21.9.4.3.4.3 The air-material separator (AMS) used with this system shall comply with the requirements of 21.9.4.4.5.1 and comply with 21.9.8.2.

21.9.4.3.4.4* The AMS shall include filtration for the separation of the conveyed combustible dust from the conveying air stream.

21.9.4.3.4.5 The air-moving device shall be downstream of the AMS.

21.9.4.3.4.6 Cyclones used as primary AMS units shall be permitted only in combination with a filtered secondary AMS.

21.9.4.3.5 Specific Requirements for Receiving and Shipping Conveyances.

21.9.4.3.5.1 All transport modes such as railcars (hopper cars, boxcars, or tank cars) and trucks (both receiving and shipping in bulk), into which or from which commodities or products are pneumatically conveyed, shall be electrically bonded to the plant ground system or earth grounded.

21.9.4.3.5.2 The requirement in 21.9.4.3.5.1 shall not apply to materials of processes involving inert materials, such as limestone at feed mills.

21.9.4.3.5.3 All connections between the transport vehicles and the plant system shall be made on the outside of the building or in a dedicated shipping/receiving area that is separated from process areas and warehouses by walls or detachment.

21.9.4.4 AMS.

21.9.4.4.1 Reserved.

21.9.4.4.2 Reserved.

21.9.4.4.3 Reserved.

21.9.4.4.4 Reserved.

21.9.4.4.5 AMS Locations.

21.9.4.4.5.1 AMS Locations.

(A) Air-material separators connected to processes that are potential sources of ignition, such as hammer mills, ovens, and direct-fired dryers, and other similar equipment placed inside or outside of buildings shall be protected in accordance with 21.9.8.2.

(B) Indoor air-material separators protected by deflagration venting shall be located adjacent to an exterior wall and vented to the outside through straight ducts not exceeding 20 ft (6 m) in length.

(C) Indoor air-material separators protected by deflagration venting shall be designed so that the explosion pressures will not rupture the ductwork or the separator.

(D)* The requirements in 21.9.8.2 shall not apply to an AMS with a dirty side volume of less than 8 ft³ (0.2 m³).

(E) Cyclones with a 30 in. (0.76 m) diameter or less used as air-material separators shall be permitted to be installed without explosion protection inside buildings when the following conditions are present:

- (1) The room, building, or other enclosure is not a Class I, Division 1 or 2 or Class II, Division 1 area as defined by Article 500 of NFPA 70.
- (2) The material being processed has a minimum ignition energy of more than 10 mJ.
- (3) The system is a closed process, excluding centralized vacuum cleaning systems.
- (4) The material being processed has a K_{St} of less than 200 bar-m/sec.

21.9.4.4.5.2* Dust Collector Location. Dust collectors shall be located outside of buildings and shall be protected in accordance with 21.9.8.2.

(A) Dust collectors shall be permitted inside of buildings if any of the following apply:

- (1) Deflagration venting is provided in accordance with the requirements of NFPA 68.
- (2) Dust collectors are equipped with an explosion suppression system designed according to NFPA 69.

(B) If the dust collector is a centrifugal separator without bags, used for removing moisture from coolers that handle pelleted, extruded, or flaked grain and feed products, it shall be permitted inside or outside of buildings without explosion protection.

(C) Bin vent dust collectors directly mounted without a hopper on a tank or bin, whose primary function is to filter air displaced during filling or blending operations and return dust directly to the bin, shall be permitted inside or outside of buildings without explosion protection. Filters that return air to inside of buildings shall be capable of a minimum efficiency of 0.008 grains per dry standard cubic foot of airflow (0.02 g per dry standard cubic meter of airflow).

(D) Filters used for classifying food products with air (product purifiers) shall be permitted to be located inside or outside of buildings without explosion protection.

21.9.4.4.6* AMS Clean Air Exhaust.

21.9.4.4.6.1* See 9.4.4.6.3.

21.9.4.4.6.2* Air from multiple pneumatic filters shall be permitted to be returned to the air makeup system.

21.9.4.4.6.3* Air from hammer mill filters shall not be returned to the air makeup system.

21.9.4.4.6.4* Air from filters used for classifying food products (purifiers) shall be permitted to be returned to the air makeup system.

21.9.4.4.6.5 Air from a multiple pneumatic conveying system, negative or positive, shall be permitted to be returned to the air makeup system.

21.9.4.5 Reserved.

21.9.4.6 Duct Systems.

21.9.4.6.1 Plastic or fiberglass ducts or pipes shall not be used.

21.9.4.6.2* Ductwork utilizing a combustible lining shall be permitted only in high impact areas.

21.9.4.6.3 Flexible hose and connectors shall comply with 21.9.6.6.1.4.

21.9.4.7 Reserved.

21.9.4.8 Reserved.

21.9.4.9 Bulk Storage Enclosures: Bins, Tanks, and Silos.

21.9.4.9.1 Construction of bins, tanks, and silos shall conform to applicable local, state, or national codes.

21.9.4.9.2* Where explosion relief vents are provided on silos, bins, and tanks, they shall operate due to overpressure before the container walls fail.

21.9.4.9.3 Access doors or openings shall meet the following requirements:

- (1) They shall be provided to permit inspection, cleaning, and maintenance and to allow effective use of firefighting techniques in the event of fire within the bin, tank, or silo.
- (2) They shall be designed to prevent dust leaks.

21.9.4.9.4 Where a bin, tank, or silo has a personnel access opening provided in the roof or cover, the smallest dimension of the opening shall be at least 24 in. (610 mm).

21.9.4.9.5* Dust bins and tanks shall comply with 21.9.4.9.5.1 and 21.9.4.9.5.2.

21.9.4.9.5.1 Bins and tanks for the storage of grain dust shall be dusttight, constructed of noncombustible materials, and located outside the buildings or structures.

21.9.4.9.5.2 The dust bins and tanks shall have transfer systems that are separated from the upstream operations by rotary valves or choke seals, or through the use of other methods to reduce the likelihood of propagation of an explosion in accordance with NFPA 69.

21.9.4.9.6 Air displacement venting of bins, tanks, and silos shall comply with 21.9.4.9.6.1 through 21.9.4.9.6.4.

21.9.4.9.6.1 The requirements for air displacement shall be as follows:

- (1) Each bin, tank, or silo shall be provided with means for air displacement during filling or emptying.
- (2) Displaced air shall not be discharged to the building atmosphere unless it is cleaned with a filter having a minimum efficiency of 0.008 grains per dry standard cubic foot of airflow (0.02 g per dry standard cubic meter of airflow).

21.9.4.9.6.2* Vents shall be designed to prevent plugging due to accumulations of dust.

21.9.4.9.6.3 Inclined vent stacks shall have clean-out doors or panels.

21.9.4.9.6.4 Bin vents shall be sized to handle the air displaced by either filling or emptying.

21.9.4.10 Reserved.

21.9.4.11 Reserved.

21.9.4.12 Reserved.

21.9.4.13 Mechanical Feeding Devices.

21.9.4.13.1* When failure of a mechanical feeding device could cause significant combustible dust hazards, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

21.9.4.13.2 Controls shall be provided to monitor the operation status of the equipment.

21.9.4.14 Bucket Elevators.

21.9.4.14.1 All Legs.

21.9.4.14.1.1 Casing, head and boot sections, access openings, and connecting spouts shall be as dusttight as practicable and shall be constructed of noncombustible materials.

21.9.4.14.1.2* Inspection openings shall be provided in the boot section to allow clean-out of the boot and inspection of the alignment of the boot pulley and belt.

21.9.4.14.1.3 Inspection openings shall be provided in the head section to allow complete inspection of the head pulley lagging, the belt and pulley alignment, and the discharge throat of the leg.

21.9.4.14.1.4* Each leg shall be independently driven by motor(s) and drive train(s) capable of handling the full-rated capacity of the elevator leg without overloading.

(A) Line shaft drives shall be acceptable for legs used in the milling industry as long as they are capable of handling the full-rated capacity of all connected equipment without overloading.

(B) Multiple motor drives shall be interlocked to prevent operation of the leg upon failure of any single motor.

(C) The drive shall be capable of starting the unchoked leg under full (100 percent) load.

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

21.9.4.14.1.6 The use of plastic, rubber, and other combustible linings shall be limited to high-impact areas and wear surfaces.

21.9.4.14.1.7 The leg head section between the up and down casings shall be sloped at an angle of not less than 45 degrees.

21.9.4.14.1.8 All spouts intended to receive grain or dry ingredients directly from any leg shall be designed and installed to handle the full-rated elevating capacity of the largest leg feeding such spouts.

21.9.4.14.1.9 Legs shall have lagging installed on the head pulley to minimize slippage.

21.9.4.14.1.10 Leg conveyor belts and lagging shall have a surface electrical resistivity not greater than 300 megaohms per square (3×10^8 ohms per square). (See A.21.9.4.15.5.)

21.9.4.14.1.11 Leg belts and lagging shall be fire resistant and oil resistant.

(A) Oil-resistant lagging or belting shall not be required for bucket elevators used in flour mills or for handling inert materials.

(B) Oil-resistant lagging or belting shall not be required for line shaft drives as used in the milling industry.

(C) Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 18.65, or the flame test for belting in Part 13.2 of ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*.

21.9.4.14.1.12* Monitors.

(A)* Inside legs shall have monitors at head, tail, and knee pulley bearings that indicate high bearing temperature or vibration detection.

(B) Inside legs shall have monitors for head, tail, and knee pulley alignment and belt alignment.

(C) Abnormal conditions shall actuate a visual or an audible and visual alarm requiring corrective action.

21.9.4.14.1.13 All garners, bins, or other receptacles into which material is spouted directly from legs, and which are not designed with automatic overflow systems, shall be equipped either with devices to shut down equipment or with high-level indicating devices with visual or audible alarms.

21.9.4.14.2* Legs Handling Bulk Raw Grain.

21.9.4.14.2.1* Legs handling bulk raw grain shall be installed either as an outside leg or as an inside leg with compliance with one of the following cases:

- (1) Legs are located within 10 ft (3 m) of an exterior wall and are vented as outlined in 21.9.4.14.2.2 to the outside of the building and designed so that the explosion pressures will not rupture the ductwork or the leg.
- (2) Legs are vented in accordance with NFPA 68.
- (3) Legs are protected in accordance with NFPA 69.

21.9.4.14.2.2* Outside legs shall be provided with explosion relief panels located at intervals no greater than 20 ft (6 m) along the casings as shown in Figure 21.9.4.14.2.2(a) and Figure 21.9.4.14.2.2(b).

(A) To minimize personnel exposure, deflagration venting for outside legs shall start between 8 ft to 12 ft (2.5 m to 3.5 m) above grade, or the bottom of the deflagration vent shall be within 1 ft to 4 ft (0.3 m to 1 m) after the leg penetrates the building roof.

(B) Venting shall not be required on portions of outside legs located below grade or passing through ground-level buildings.

(C) Each side vent shall have a minimum area equivalent to two-thirds of the cross-sectional area of the leg casing.

(D) A single face vent shall be permitted to replace a pair of opposing side vents in those portions of a double-casing leg where either of the following situations exists:

- (1) Side venting could expose personnel on access ladders or platforms.
- (2) Structural interferences are present that would interfere with vent operation.

(E) Single face vents shall be equal to the area of two side vents [four-thirds of the cross-sectional area of the leg casing as indicated in Figure 21.9.4.14.2.2(b)].

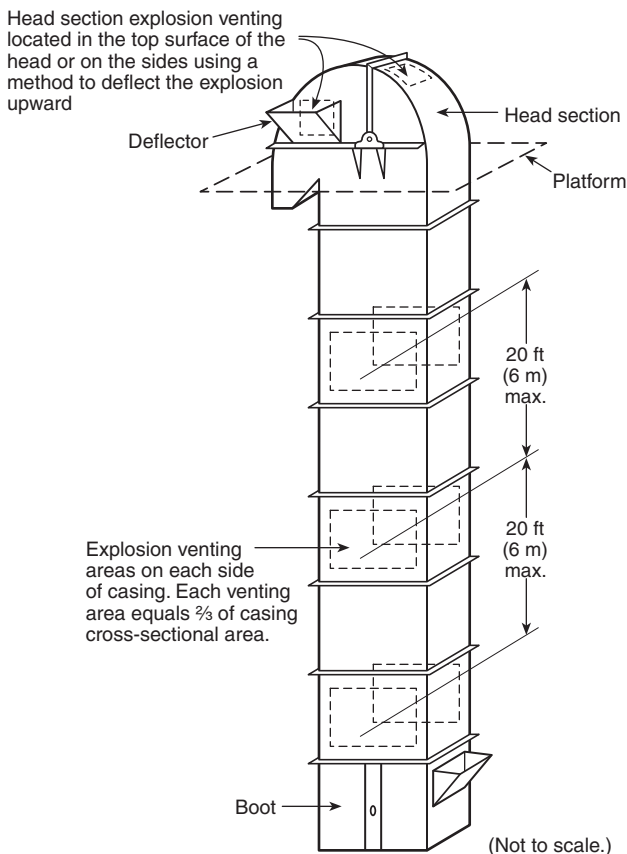


FIGURE 21.9.4.14.2.2(a) Typical Elevator Deflagration Venting for a Single Casing Leg.

(F) The head section of bucket elevators shall be provided with deflagration vents in the top surface or on the sides using a method to deflect the explosion upward. The vent area shall be a minimum of 5 ft² (0.46 m²) of vent area per 100 ft³ (2.83 m³) of head section volume. The largest vent area as practicable shall be used in the head section to help minimize the development of explosive pressure. Vents shall deploy when an internal pressure of 0.5 psi to 1.0 psi (3.5 kPa to 6.9 kPa) occurs.

(G) Explosion relief panels shall be provided on the leg housing so the ducts will not be a collection point for dust during normal operations.

21.9.4.14.3 Legs Handling Materials Other Than Bulk Raw Grain That Present an Explosion Hazard.

21.9.4.14.3.1 Deflagration venting of legs into buildings shall not be permitted unless a flame-arresting and particulate retention vent system in accordance with NFPA 68 is used.

21.9.4.14.3.2* Outside legs shall be equipped with deflagration venting in accordance with 21.9.4.14.2.2.

(A) The requirement in 21.9.4.14.3.2 shall not apply to those portions of outside legs, as defined in this standard, below grade or passing through ground-level buildings.

21.9.4.14.3.3* Legs or portions of legs that are located inside shall have the maximum practicable explosion relief area

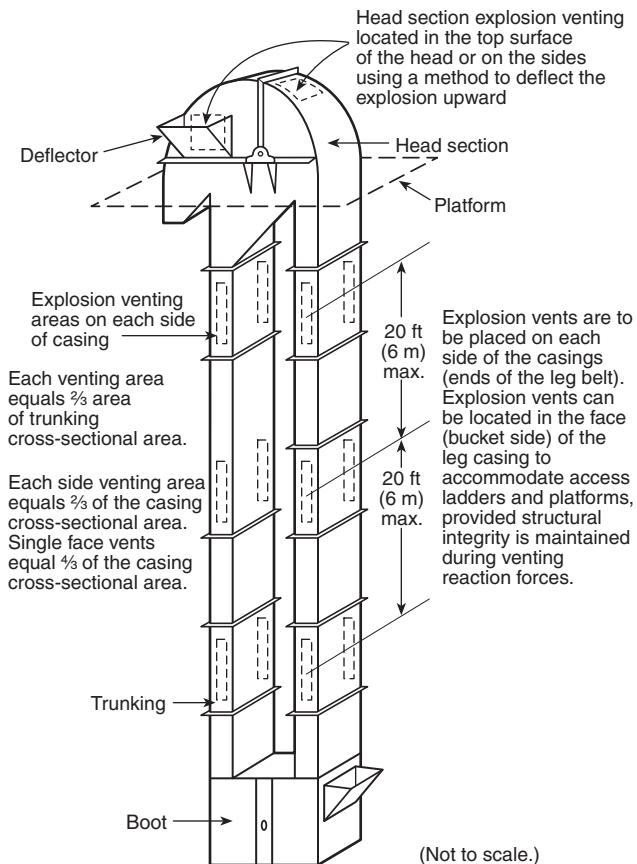


FIGURE 21.9.4.14.2.2(b) Typical Elevator Deflagration Venting for a Double Casing Leg.

directly to the outside, a flame-arresting and particulate retention vent system in accordance with NFPA 68, or explosion suppression in accordance with NFPA 69.

21.9.4.15* Conveyors and Spouts.

21.9.4.15.1* When an enclosed conveying device could cause significant combustible dust hazards, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

21.9.4.15.2* Enclosed conveyors shall be designed to either relieve or stop if the discharge end becomes plugged.

21.9.4.15.3 Bulk material conveyor belts shall have belt alignment and hot bearing sensors at the head and tail.

21.9.4.15.4 Housings for enclosed conveyors (e.g., screw conveyors and drag conveyors) shall be designed to prevent escape of combustible dusts.

21.9.4.15.5* Bulk material conveyor belts and lagging shall have a surface electrical resistivity not greater than 300 megaohms per square (3×10^8 ohms per square) and shall be fire resistant and oil resistant.

21.9.4.15.5.1 Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 18.65, or the flame test for belting in Part 13.2 of

ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*.

21.9.4.15.6 Fixed spouts shall be dusttight.

21.9.4.15.7* Use of combustible lining shall be permitted in spouts and other handling equipment at impact points and on wear surfaces.

21.9.4.15.8 Portable, automatic distributing, and movable spouts shall be permitted in work areas, bin areas, and distribution areas and shall be as dusttight as practicable when in use.

21.9.4.15.9* Spouts that direct material into bins, tanks, or silos shall be designed and installed so that any foreign objects, such as metal or stones, in the material stream do not strike the walls of the container, as far as is practicable.

21.9.4.16 Mixers and Blenders.

21.9.4.16.1 Mixers and blenders shall be designed to control fugitive dust emissions.

21.9.4.16.2* Foreign materials that can become ignition sources shall be prevented from entering the mixer or blender.

21.9.4.16.3 Clearance and alignment of moving parts in equipment 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.

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

21.9.4.16.5* Where an explosion hazard exists as described in Chapter 7 and Section 21.7, protection shall be in accordance with Section 9.8 and 21.9.8.

21.9.4.16.6 Where a fire hazard exists, protection shall be in accordance with Section 9.9 and 21.9.9.

21.9.4.17 Dryers.

21.9.4.17.1 Reserved.

21.9.4.17.2* General Requirements. This section shall apply to grain, commodity product, spray, and starch dryers.

21.9.4.17.2.1 Dryers, within the scope of this standard, shall function to process materials that are subjected to heated air for the purpose of reducing their moisture content.

21.9.4.17.2.2* Other dryers used in further processing of agricultural commodities shall be outside the scope of this standard.

21.9.4.17.2.3* Dryers and auxiliary equipment shall be designed, operated, cleaned, and maintained to minimize combustible accumulations on those inside surfaces intended to be free of grain or product during drying.

21.9.4.17.2.4 Where an explosion hazard exists, protection shall be in accordance with 21.9.8.2.

21.9.4.17.3* Grain Dryers.

21.9.4.17.3.1* Location.

(A) Dryers shall be located so as to minimize fire exposure to adjacent buildings and structures, including other dryers, to minimize ignition potential to operating and storage areas, and to provide access for firefighting.

(B) Dryers shall not be located inside grain-handling or grain storage structures.

21.9.4.17.3.2 Construction.

(A) Dryers and related equipment shall be designed so that the fire hazard inherent in equipment operating at elevated temperatures is minimized.

(B) Dryers designed to recirculate a portion of the exhaust air shall have a means to minimize entrained particles from being reintroduced into the drying chamber.

(C) Outward opening doors or openings shall be provided to allow access to all parts of the dryer and connecting spouts, inlet or outlet hoppers, and conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams.

(D) In case of fire, dryers shall be designed with means for unloading (emergency dumping) of the dryer contents to a safe outside location in which the location and the manner does not cause fire exposure to adjacent buildings, structures, or equipment.

(E) A method shall be provided for the safe handling of burning material and for the extinguishment of the burning material as it is emptied from the dryer.

21.9.4.17.3.3 Air Heating Systems.

(A)* Air heating systems shall include the heat source and associated piping or wiring and the circulating fan and associated ductwork used to convey the heated air to the dryer.

(B)* The air heater and its components shall be selected for the intended application, shall be compatible with the types of fuels to be used, and shall be designed for the temperatures to which they will be subjected.

(C) Direct-fired air heating systems shall have a means to minimize airborne combustible material from entering the drying chamber.

(D) Burner systems and their controls for dryers fired by fuel oil, natural gas, mixed gas, manufactured gas, or liquefied petroleum gas, as well as mixing components, shall comply with NFPA 86.

(E) Liquefied petroleum gas vaporizing burner installations shall comply with NFPA 58.

(F) Fuel systems, up to the point of connection to the burner, shall comply with the following as applicable:

- (1) NFPA 30
- (2) NFPA 31
- (3) NFPA 54
- (4) NFPA 58

21.9.4.17.3.4 Safety Controls.

(A) Safety controls shall be designed, constructed, and installed such that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained.

(B) The dryer and its auxiliary equipment shall be equipped with excess temperature limit controls arranged to supervise both of the following:

- (1) Airstream between the fuel burner and the drying chamber air inlet
- (2) Airstream at the discharge of the cooling and heating sections

(C) Excessive temperatures detected by devices required by 21.9.4.17.3.4(B) shall initiate an automatic shutdown.

(D) The automatic shutdown in 21.9.4.17.3.4(C) shall accomplish all of the following:

- (1) Shut off the fuel or heat to the burners.
- (2) Stop the flow of product out of the dryer.
- (3) Stop all airflow from fans into the dryer.
- (4) Sound an alarm at a constantly attended location or for the operator, or both, to prompt an emergency response.

(E) An emergency stop shall be provided that will enable manual initiation of the automatic shutdown in 21.9.4.17.3.4(C).

(F) All safety control equipment shall be nonrecycling and shall require manual reset before the dryer can be returned to operation.

21.9.4.17.3.5 Dryer Operation.

(A) Operating controls shall be designed, constructed, and installed so that required conditions for safe operation of the air heater, dryer, and ventilation equipment are maintained.

(B) The drying chamber shall have an operating control that maintains the temperature within prescribed limits.

(C) Extraneous material that is not normally part of the grain as it is received from the farm and that would contribute to a fire hazard shall be removed before it enters the dryer.

21.9.4.17.3.6 Fire Detection and Protection.

(A) A fire detection system shall be provided for the dryer when the operation is intermittent during the drying season and the dryer is shut down full or partially full of grain.

(B) The fire detection system in 21.9.4.17.3.6(A) shall sound an alarm in a constantly attended location.

(C) The fire detection system in 21.9.4.17.3.6(A) shall be permitted to be deactivated when the dryer has been thoroughly emptied and cleaned or when the dryer has been emptied, cleaned, and secured at the end of the drying season.

(D) When operating practices prohibit the retention of any grain in the dryer during intermittent unattended shutdowns, a fire detection system shall not be required.

(E)* Means shall be provided for extinguishing fires within the drying chamber.

21.9.4.17.4 Product Dryers.

21.9.4.17.4.1 Drying units shall be equipped with remote power cutoff switches.

21.9.4.17.4.2 On direct-fired dryers, the air supply shall be filtered of all particles that could be a combustion hazard.

21.9.4.17.4.3 Fuel systems, up to the point of connection to the dryer burner, shall comply with the following as applicable:

- (1) NFPA 30
- (2) NFPA 31
- (3) NFPA 54
- (4) NFPA 58

21.9.4.17.4.4 Direct-fired dryers with an explosion hazard located within buildings shall be protected in accordance with 21.9.8.2.

21.9.4.17.4.5 The combustion and burner system and controls shall be designed, operated, and tested as required in NFPA 86.

21.9.4.17.5 Starch Dryers.

21.9.4.17.5.1 General. Starch dryers shall be designed and located in accordance with the requirements of 21.9.4.17.3.1 through 21.9.4.17.3.2(E).

21.9.4.17.5.2 Ignition Sources.

(A)* The interior heated surface of a starch dryer shall be designed and maintained to prevent the accumulation of starch that can attain a thickness or depth of ½ in. (13 mm) or more.

(B)* Inspection and clean-out doors shall be located at points in the system where spontaneous ignition is likely to occur, specifically where starch can build up and where starch is subject to continuous heat.

(C) Inspection and cleaning of the areas in 21.9.4.17.5.2(A) and 21.9.4.17.5.2(B) shall be performed to minimize starch accumulations.

(D) The combustion and burner systems and controls shall be designed, operated, and tested as required in NFPA 86.

21.9.4.17.5.3 Fire Detection, Alarm, and Interlocking Systems.

(A) Every dryer shall have the means for detecting abnormal conditions that indicate the presence or potential of a fire.

(B) The detection of these conditions in 21.9.4.17.5.3(A) shall activate an alarm and automatically shut down the equipment and activate the extinguishing system.

(C) The design of an automatically-operated extinguishing system in 21.9.4.17.5.3(B) shall include provisions for the necessary personnel protective features required for inspection and cleaning of the dryers.

(D) The dryer system, including auxiliary ducts, fans, and conveyors, shall be interlocked to provide a safe and orderly shutdown in the event of mechanical failure or abnormal operating conditions.

21.9.4.17.5.4 Suppression and Extinguishing Systems.

(A)* Each dryer located inside a building shall be protected by a permanently installed fire protection system, explosion suppression system, or both, in accordance with applicable NFPA standards.

(B) The system in 21.9.4.17.5.4(A) shall be actuated by fire or explosion detection devices that will sound an alarm and sequentially shut down the dryer.

(C) The fire extinguishing system in 21.9.4.17.5.4(A) shall be capable of manual actuation from locations that will be accessible during a fire in the dryer.

(D) The dryer shall not be returned to production until the fire protection or explosion suppression system in 21.9.4.17.5.4(A) has been restored.

(E) Piping for extinguishing systems shall be located to minimize the possibility of destruction in case of an explosion.

(F) The water supply for fire protection to buildings subject to explosion hazards shall be sectionalized in such a way that a water line break from an explosion can be readily isolated.

21.9.4.17.6 Spray Dryer Systems.

21.9.4.17.6.1 General.

(A) Spray dryer systems shall include the spray dryer and associated fluid bed dryers, cyclones, and dust collectors with the connecting duct work.

(B) A DHA, in accordance with Chapter 7 and Section 21.7, shall be performed on all spray dryer systems.

(C) The DHA shall address the proper sequence of startup, shutdown, emergency stop, and normal operation.

(D) Spray dryers shall be designed and located in accordance with the requirements of 21.9.4.17.3.1 through 21.9.4.17.3.2(E).

21.9.4.17.6.2 Safety Controls.

(A) Safety controls shall be designed, constructed, and installed such that required conditions of safety for operation of the air heater, dryer, and ventilation equipment are maintained.

(B) The dryer and its auxiliary equipment shall be equipped with excess temperature limit controls arranged to supervise following:

- (1) Airstream between the air heater and the drying chamber air inlet
- (2) Airstream at the discharge of the cooling and heating sections

(C) Excessive temperatures detected by devices required by 21.9.4.17.6.2(B) shall initiate an automatic shutdown.

(D) The automatic shutdown in 21.9.4.17.6.2(C) shall accomplish all of the following:

- (1) Shut off the fuel to the burners or heating system.
- (2) Stop the flow of product out of the dryer.
- (3) Stop all airflow from fans into the dryer.
- (4) Sound an alarm at a constantly attended location or for the operator, or both, to prompt an emergency response.

(E) An emergency stop shall be provided that will enable manual initiation of the automatic shutdown in 21.9.4.17.6.2(C).

(F) All safety control equipment shall be nonrecycling, requiring manual reset before the dryer can be returned to operation.

21.9.4.17.6.3 Dryer Operation.

(A) Operating controls shall be designed, constructed, and installed so that required conditions of safety for operation of the air heater, dryer, and ventilation equipment are maintained.

(B) The drying chamber shall have an operating control that maintains the temperature within prescribed limits.

21.9.4.17.6.4 Fire Detection.

(A) Every dryer shall have the means for detecting abnormal conditions that indicate the presence or potential of a fire.

(B) The detection of the conditions in 21.9.4.17.6.4(A) shall activate an alarm and automatically shut down the equipment.

(C)* Means shall be provided for extinguishing fires within the drying chamber.

21.9.4.17.6.5 Explosion Protection.

(A) Spray dryer systems shall be protected in accordance with 21.9.8.2 unless a documented risk assessment determines a different level of protection is required.

(B) Where installed, the explosion protection system shall be connected to the process control system. On a signal from the explosion control system, the process shall be shut down automatically.

(C) Where required, the explosion protection system shall be designed in accordance with NFPA 69 or NFPA 68, or a combination of the two as determined appropriate by the DHA.

(D) CO differential early fire detection and suppression systems shall be allowed as a tool to prevent deflagrations from occurring per the requirements of NFPA 69.

(E) Where installed, the explosion protection system shall be permitted to be deactivated automatically during clean-in-place functions.

21.9.4.18 Reserved.

21.9.4.19 Heat Transfer Operations.

21.9.4.19.1* Heat Transfer Systems.

21.9.4.19.1.1 Heat transfer devices utilizing air, steam, or vapors of heat transfer fluids shall be provided with pressure-relief valves where necessary.

(A) Relief valves on systems employing combustible heat transfer media shall be vented to a safe outside location.

21.9.4.19.1.2 Heaters and pumps for combustible heat transfer fluids shall be located in a separate, dust-free room or building of noncombustible construction.

(A) Buildings or rooms that contain heaters and pumps for combustible heat transfer fluids shall be protected by automatic sprinklers designed in accordance with NFPA 13 to control a fire involving the combustible heat transfer fluid.

(B) Air for combustion shall be taken from a clean outside source.

(C)* Buildings or rooms that contain heat transfer equipment and boilers that use combustible heat transfer fluids shall be located in separate areas such that they do not communicate directly with areas that contain a dust explosion hazard.

(D) Where combustible heat transfer fluids are used, doorways shall be curbed or ramped and floor drains shall be provided to direct spills of the heat transfer fluid to a safe location.

(E) Automatic sprinkler protection designed to control fires involving the fluids in 21.9.4.19.1.2(D) shall be provided in areas containing equipment that uses these fluids and in areas containing storage tanks for these fluids.

21.9.4.19.1.3 Enclosures for heat exchangers shall be constructed of noncombustible materials and shall have access openings for cleaning and maintenance.

21.9.4.19.1.4* Heat exchangers shall be located and arranged in a manner that does not allow combustible dust to accumulate on coils, fins, or other heated surfaces.

21.9.4.19.1.5 Heaters for heat transfer systems shall be provided with operating controls in accordance with NFPA 86.

21.9.4.19.2 Comfort Heating.

21.9.4.19.2.1 In areas containing combustible dust, comfort heating, if provided, shall be appropriately rated for the area as defined in NFPA 70.

21.9.4.19.2.2 Boilers used to provide hot water or low-pressure steam for comfort heating shall be located in a nonhazardous area and shall be installed in accordance with the requirements of 21.9.4.19.1.2.

21.9.4.19.2.3 Steam or hot water supply pipes and hot air supply ducts to comfort areas shall be fitted with insulation having a continuous, nonporous covering and an insulation quality sufficient to keep the temperatures of the outer surface below 140°F (60°C) for personnel safety purposes and less than 250°F (121°C) for prevention of dust ignition.

21.9.4.20 Ventilation and Venting.

21.9.4.20.1 General.

21.9.4.20.1.1 In this section, ventilation shall refer to natural or mechanical movement of air necessary for normal operation and personnel comfort and safety.

21.9.4.20.1.2 Recirculating or recycling exhaust air ventilation systems for dust explosion hazard areas, if used, shall be equipped with filter systems capable of removing dust from the air.

21.9.4.20.1.3 Dust collection systems used in conjunction with ventilation systems shall comply with the provisions of 21.9.4.3.3.

21.9.4.21 Processing Machinery and Equipment.

21.9.4.21.1* General.

21.9.4.21.1.1 Receiving systems prior to the leg shall be equipped with one or more devices such as grating, wire mesh screens, permanent magnets, listed electromagnets, pneumatic separators, or specific gravity separators, to minimize or eliminate tramp material from the product stream.

(A) Barge and ship receiving systems using legs as the primary reclaiming systems shall be allowed to have the tramp material protection after the unloading leg but prior to being handled in another leg or processing equipment.

21.9.4.21.1.2* Where tributary spouts or conveyors feed whole grain or grain products for size reduction into grinders, pulver-

izers, or rolling mills, they shall be equipped with properly installed permanent magnets or listed electromagnets, pneumatic separators, specific gravity separators, scalpers, or screens to exclude metal or foreign matter of a size larger than the grain being processed as far as is practicable.

21.9.4.21.1.3* Equipment shall be bonded and grounded to dissipate static electricity.

21.9.4.21.1.4 All processing machinery and components, such as magnets, shall be mounted to facilitate access for cleaning.

(A) The requirement in 21.9.4.21.1.4 shall not apply where processing machinery is mounted on a tight-fitting base that prevents material from reaching inaccessible places beneath the machine.

21.9.4.21.1.5 Screw, drag, or en-masse conveyors shall be fully enclosed in metal housings and shall be designed to either relieve or stop if the discharge end becomes plugged.

21.9.4.21.2 Starch Processing Machinery and Equipment.

21.9.4.21.2.1 Carbon steel shall be avoided in the grinding chambers and moving parts of grinding mills in favor of brass, bronze, stainless steel, and other metals with lower sparking potential.

21.9.4.21.2.2 The reels or sieves of screens, scalpers, and similar devices shall be in dusttight enclosures.

21.9.4.21.2.3 Connecting ducts shall be one of the following:

- (1) Metal
- (2) Electrically conductive nonmetallic flexible connecting ducts having an electrical resistance not greater than 1 megaohm (1×10^6 ohms)

(A) The requirement in 21.9.4.21.2.3 shall not apply to plastic tubing used for sample delivery systems.

21.9.4.21.2.4 Where more than one material source is connected to a common conveyor, air-material separator, or similar device, each source that is connected shall be equipped with a method to prevent propagation of a deflagration in accordance with NFPA 69.

21.9.4.21.2.5 Dry milling or grinding of starch shall be performed in a separate building with explosion relief or in a separate room isolated from other areas by interior walls designed according to 9.3.5.2.3.

(A) The requirement in 21.9.4.21.2.5 shall not apply if the equipment can be designed to be protected in accordance with NFPA 69 by deflagration containment, explosion suppression, or inerting the volume to reduce oxygen such that combustion is not supported.

(B) The requirement in 21.9.4.21.2.5 shall not apply if mills are provided with deflagration venting to a safe outside location. If deflagration vents ducts longer than 3 m (10 ft) are to be used, the milling equipment and deflagration vent duct shall be designed to withstand the increased vented explosion pressure.

21.9.5 Dust Control.

21.9.5.1* General. Dust control as used in 21.9.5 shall be the control of emission of airborne combustible dusts from process and conveying equipment or material transfer points.

21.9.5.1.1* Suppressants shall be permitted to be used for dust control.

21.9.5.1.2 In grain elevators, a method to prevent the escape of dust into surrounding areas shall be provided at leg boot sections, belt loaders, belt discharge or transfer points, trippers, turnheads, or distributors, and on unfiltered vents from which dust could be emitted into interior areas with displaced air.

21.9.5.1.3 Packaging and weighing systems, including fixed-scale hoppers and upper and lower bins and garners, shall be enclosed and equipped with a venting system or air aspiration to collect the dust normally emitted by rapid air displacement during filling and emptying, if necessary.

21.9.5.1.4 All machinery such as cleaners, scalpers, and similar devices normally used inside structures but not designed to be dusttight shall be provided with a means of controlling combustible dusts, if present.

21.9.5.1.5* Collected grain dust shall be permitted to be returned to the grain stream prior to or after being handled in a leg. Dust alone shall not be added directly to the leg and handled by itself. However, dust shall be permitted to be handled in an outside located leg that is used as part of a dust loadout system.

21.9.5.1.6 Dust returned to handling equipment other than a leg, storage, or process shall be returned downstream of the collection point in such a manner that it will not create dust emissions.

21.9.5.1.7* A point-of-use dust collector shall be permitted to be mounted directly to conveying equipment in both indoor and outdoor locations, provided all of the following conditions are met:

- (1) When the point-of-use dust collector is mounted to an enclosure, such as a bucket elevator leg, the enclosure shall have explosion protection per the provisions of this standard. The volume of the dirty air side and of the transition shall be included in the determination of explosion protection design.
- (2) The point-of-use dust collector shall be mounted directly to the conveying equipment housing via a transition duct without an airlock.
- (3) The transition between the point-of-use dust collector and the vented equipment shall be designed such that dust will release from the filter media and return to the equipment product stream and the transition is not a collection point for dust accumulation under normal operations.
- (4) The cross-sectional area of the transition connection shall be equal to or greater than the cross-sectional area of the point-of-use dust collector.
- (5) The point-of-use dust collector shall include an integral air-moving device on the clean side of the dust collector to maintain negative pressure.
- (6) The point-of-use dust collector shall not be connected to any other pieces of equipment.
- (7)* Point-of-use dust collectors that return air to the inside of buildings shall be capable of a minimum filtering efficiency of 0.008 grains per dry standard cubic foot of airflow (0.02 g per dry standard cubic meter of airflow).

21.9.6 Ignition Source Control.

21.9.6.1 Reserved.

21.9.6.2 Reserved.

21.9.6.3 Reserved.

21.9.6.4 Bearings.

21.9.6.4.1 Antifriction bearings shall be used on all machinery, conveyors, legs, and processing equipment.

21.9.6.4.1.1 Sleeve and friction-type bearings, plastic bearings, or oil-impregnated wood bearings shall be permitted for equipment operating at 150 rpm or less.

21.9.6.4.2 All bearings shall be maintained per manufacturers' recommendations and shall be kept free of dust, product, and excessive lubricant.

21.9.6.4.3 If a bearing is directly exposed to a combustible dust atmosphere that poses a deflagration hazard or is subject to dust accumulation that poses a deflagration hazard, the bearing shall be monitored for overheating by automated equipment, installed devices, or periodic manual checks on a frequency established by the owner/operator.

21.9.6.4.4* All bearings on legs and conveyors shall be located outside of machinery enclosures and isolated from the product stream to minimize exposure to dust and to be more accessible for inspection and service.

21.9.6.4.4.1 Antifriction support bearings on screw conveyors and similar equipment requiring bearings to be within the product stream shall be of the sealed type.

21.9.6.4.4.2 Sleeve and friction-type bearings shall be permitted for equipment operating at 150 rpm or less.

21.9.6.5 Reserved.

21.9.6.6* Electrostatic Discharges. Static electricity shall be dissipated by using bonding and grounding.

21.9.6.6.1 Conductive Equipment.

21.9.6.6.1.1 Reserved.

21.9.6.6.1.2 Reserved.

21.9.6.6.1.3 Reserved.

21.9.6.6.1.4 Flexible Connectors (see A.9.6.6).

(A) Sections 21.9.6.6.1.4(B) and 21.9.6.6.1.4(C) shall be permitted to be used in lieu of 9.6.6.1.4.

(B)* The piping system on both ends of a flexible connector shall be properly grounded.

(C)* Flexible connectors and hoses shall conform to at least one of the following provisions:

- (1) It is made of static dissipative construction.
- (2) It is less than 24 in. (610 mm) in length.
- (3) It is made of knitted fabric construction.
- (4) It is bonded to the piping system on each end, with a wire spiral integral to the flexible connector.

21.9.6.6.2* Maximum Particulate Transport Rates. (Reserved)

21.9.6.7 Reserved.

21.9.6.8 Industrial Trucks. See 21.9.6.15.

21.9.6.9 Reserved.

21.9.6.10 Reserved.

21.9.6.11 Reserved.

21.9.6.12 Reserved.

21.9.6.13 Reserved.

21.9.6.14 Electrical Systems.

21.9.6.14.1 Electrical wiring and equipment shall comply with *NFPA 70*.

21.9.6.14.2* Electrical wiring and equipment in areas meeting the definition of Class II, Group G, Division 1 or 2 according to Article 500 of *NFPA 70* shall comply with Article 502 of *NFPA 70*.

21.9.6.14.2.1 The requirement in 21.9.6.14.2 shall not apply to electrical equipment that has been listed and installed as intrinsically safe according to Article 504 of *NFPA 70*.

21.9.6.14.2.2 The requirement in 21.9.6.14.2 shall not apply to electrical equipment that is housed in an enclosure that meets the applicable requirements of *NFPA 496*.

21.9.6.15 Engine-and Motor-Driven Equipment.

21.9.6.15.1 Engine- and motor-driven equipment used in confined Class II, Group G, Division 2 operating areas shall be equipped with safety devices designed to reduce the potential fire hazard and electrical shock hazard.

21.9.6.15.2 Engine- and motor-driven equipment shall meet the requirements of *NFPA 505*.

21.9.6.15.2.1* Front-end loaders or similar equipment used in flat storage areas or marine vessels to handle grain, meal, hulls, or other agricultural commodities shall not be required to meet the requirements of *NFPA 505*.

21.9.6.15.3 Spark arresters shall be used on the exhaust stacks of all diesel-powered units.

21.9.6.15.3.1 The requirement in 21.9.6.15.3 shall not apply to engines equipped with turbo-chargers.

21.9.6.15.3.2 The requirement in 21.9.6.15.3 shall not apply to road vehicles, such as grain delivery vehicles, locomotives, and other vehicles that do not operate in combustible dust-producing areas.

21.9.6.15.4* Refueling shall be conducted outdoors.

21.9.6.15.5* Surface dust shall be removed from engine- and motor-driven equipment at regular intervals during operation.

21.9.6.15.5.1 Cleaning of front-end loaders or other motor-driven equipment with compressed air shall not be conducted in hazardous locations.

21.9.6.15.5.2 Spark arresters shall be cleaned or replaced according to the manufacturer's recommendation.

21.9.6.15.6 Maintenance procedures shall comply with the manufacturer's instructions regarding replacement of insulation, covers, electrical enclosures, and parts of the electrical system designed to reduce chafing of insulation or termination failure.

21.9.6.16 Drive Belts.

21.9.6.16.1 Where a drive belt is used, the drive train shall be designed with a minimum service factor of 1.5 or higher if the manufacturer of the drive components recommends a higher service factor for continuous service for the type of equipment to be driven.

21.9.6.16.1.1 The requirement in 21.9.6.16.1 shall not apply to line shaft drives as used in the milling industry.

21.9.7 Reserved.

21.9.8 Explosion Prevention and Protection.

21.9.8.1* General. Explosion prevention, relief, and venting, as used in this standard, shall encompass the design and installation of devices and systems to vent the gases and overpressure resulting from a deflagration occurring in equipment, rooms, buildings, or other enclosures so that damage is minimized.

21.9.8.1.1* Enclosure Requirements.

21.9.8.1.1.1* If a dust explosion hazard exists in rooms, buildings, or other enclosures under normal operating conditions, such areas shall be provided with explosion relief venting distributed over the exterior walls (and roof, if applicable) in accordance with *NFPA 68*.

(A) The design of such explosion relief venting shall consider the limitations imposed by the structural design of the area.

(B) The design shall offer the least possible resistance to explosion pressures.

(C)* Explosion relief panels, windows, or other venting devices shall be designed to prevent reclosing after relieving the explosion pressure and shall be attached to retention cables or restrained by equivalent means such that they will not become a hazardous projectile upon relief.

(D) The requirement in 21.9.8.1.1.1 shall not apply to tunnels and pits where deflagration venting is not practical due to confinement by soil, building constraints, or both.

21.9.8.2* Equipment Protection.

21.9.8.2.1 When 9.8.2.2 is used for explosion protection applications in agricultural dust processes, the safety logic solver, sensors, and final elements used to perform safety functions shall be permitted to be certified to achieve a minimum safety integrity level 1 (SIL-1) rather than what is required in 15.5.5.1 of *NFPA 69*.

21.9.8.2.2* The requirement in 21.9.8.1.1.1 shall not apply to bins and silos where deflagration venting is not practical due to bin or silo geometry, building constraints, or both.

21.9.8.2.3* If deflagration venting in accordance with 9.8.2.2(2) is used, the vented material shall be directed to a safe, outside location away from platforms, operator controls, means of egress, or other potentially occupied areas.

21.9.8.3 Equipment Isolation.

21.9.8.3.1* Isolation of Equipment.

21.9.8.3.1.1 Where a DHA has determined that isolation is necessary, isolation shall be provided to prevent deflagration propagation between connected equipment in accordance with *NFPA 69*.

21.9.8.3.2* Deflagration Isolation of Upstream Areas.

21.9.8.3.2.1* Where a DHA has determined that isolation is required, isolation shall be provided to prevent deflagration propagation from equipment through upstream ductwork to the work areas in accordance with NFPA 69.

21.9.9* Fire Protection.

21.9.9.1 General. Where installed, supervisory services shall comply with NFPA 72.

21.9.9.2 Reserved.**21.9.9.3 Reserved.****21.9.9.4 Hose, Standpipes, Hydrants, and Water Supply.****21.9.9.4.1 Standpipes and Hose.**

21.9.9.4.1.1 Standpipes and hoses, where installed, shall comply with NFPA 14.

21.9.9.4.1.2* Wet or dry standpipes shall be provided to all operating areas of head houses, processing structures with operating areas, and grain bin galleries located over 50 ft (15 m) above grade.

(A) If an adequate water supply is not available to feed the standpipe either through a fixed installation or fire department water truck, then a standpipe shall be permitted to be omitted.

(B) If the employees are not expected to fight the fire with hose, and the fire department will not fight the fire using the standpipe, then a standpipe shall be permitted to be omitted.

21.9.9.4.1.3* Wet or dry standpipes shall be installed in warehouses and packing areas with combustible contents where required by the AHJ.

(A) The requirement in 21.9.9.4.1.3 shall not apply to bulk storage warehouses.

21.9.9.5 Automatic Sprinklers. Water-based extinguishing systems shall be maintained in accordance with NFPA 25.

21.10 Emergency Planning and Response.**21.10.1 Reserved.****21.10.2 Reserved.****21.10.3* Firefighting Operation.**

21.10.3.1 Fires, when discovered, shall be reported promptly to facility management and emergency responders, including the fire department.

21.10.3.2 Burning material shall not be transferred into legs.

21.10.3.3 If a fire cannot be controlled promptly in its incipient stage, the endangered structure(s) shall be evacuated.

21.10.3.4 Bearing fires shall be extinguished with a gentle application of water fog onto the bearing for cooling.

21.10.3.4.1 If water is not available, other means of extinguishment shall be permitted to be used on the bearing fire, provided caution is taken to avoid the suspension of combustible dust.

21.10.3.4.2 If the bearing is located inside equipment, material flow shall be stopped, equipment shall be shut down, and extreme caution shall be used when equipment is opened.

Chapter 22 Combustible Metals

22.1 Administration.

22.1.1* Scope. This chapter provides requirements for the production, processing, finishing, handling, recycling, storage, and use of all metals and alloys that are in a form that is capable of combustion or explosion.

22.1.1.1* The procedures in Section 22.5 shall be used to determine whether a metal is in a noncombustible form.

22.1.1.2 Combustible Metals.

22.1.1.2.1 This chapter provides requirements for operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible metal in any form.

22.1.1.2.2* This chapter shall apply to the storage or use of ignitable fibers/flyings, specifically with regard to fire hazards.

22.1.1.2.3* Operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible metals shall include, but shall not be limited to, machining, sawing, grinding, sanding, buffing, polishing, and thermal spraying.

22.1.1.3* Metals, metal alloy parts, and those materials, including scrap and mixtures, shall be subject to the requirements of the metal whose combustion characteristics they most closely match.

22.1.1.4 Metals, metal alloy parts, and those materials and mixtures, including scrap, not covered by a specific metal chapter, are subject to the requirements of Section 22.18.

22.1.1.5 Materials submitted for recycling or waste disposal shall be subject to the requirements of Section 22.19.

22.1.1.6* This chapter provides requirements for mixtures that contain metals exhibiting combustion characteristics of

metals covered by this chapter. (See 22.5.2.4 for additional information on testing and characterization.)

22.1.1.6.1 Metal only mixtures shall be subject to the requirements of this chapter.

22.1.1.6.2* Metal-containing mixtures that also contain combustible nonmetal dusts shall be permitted to be excluded from this chapter and protected according to Chapters 1 through 10 and Chapter 25 or another NFPA industry- or commodity-specific standard, if it is established by testing that the mixture meets all of the following criteria:

- (1) It has been demonstrated that mixture fires can be controlled safely and effectively with Class A:B:C fire-extinguishing agents.
- (2) It has been demonstrated that mixture fires can be controlled safely and effectively with water.
- (3) The material is not a UN Class 4.3 solid as tested using UN Class 4.3 water reactivity test methods.
- (4) It has been demonstrated that the volume resistivity is greater than 1 M ohm-m.
- (5) It is not a mixture of metal and metal-oxide that can undergo an exothermic oxidation-reduction(thermite) reaction.

22.1.1.7* This chapter shall not apply to the transportation of metals in any form on public highways and waterways or by air or rail.

22.1.1.8 This chapter shall not apply to the primary production of aluminum, magnesium, and lithium.

22.1.1.9 This chapter shall apply to laboratories that handle or use more than ½ lb (0.23 kg) of alkali metals or 2 lb (0.907 kg) aggregate of other combustible metals, excluding alkali metals.

22.1.1.9.1 Applicability thresholds for storage in laboratories shall follow the appropriate occupancy classification as designated by NFPA 45 and threshold quantities per Table 22.1.1.9.1.

Table 22.1.1.9.1 Applicability Thresholds by Occupancy

Occupancy Class (as defined in NFPA 5000)	Threshold Quantity (lb)	Threshold Quantity (kg)
Assembly	1	0.454
Educational	½ lb of alkali metals or 2 aggregate of other combustible metals, excluding alkali metals	0.23 kg of alkali metals or 0.907 aggregate of other combustible metals, excluding alkali metals
Day care	Not permitted	Not permitted
Health care	2	0.907
Ambulatory health care	2	0.907
Detention and correctional	Not permitted	Not permitted
Residential	2	0.907
Residential board and care	Not permitted	Not permitted
Mercantile	2	0.907
Business	10 for storage; 0 for use and handling	4.535
Industrial	5	2.268
Storage	50	22.675

22.1.1.10 All alkali metals and metals that are in a form that is water reactive shall be subject to this chapter.

22.1.1.11* If the quantity of a combustible metal listed in Table 22.1.1.9.1 is exceeded in an occupancy, the requirements of this document shall apply.

22.1.2 Reserved.

22.1.3 Application.

22.1.3.1 The provisions of this chapter shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion.

22.1.3.2 This chapter shall modify and augment the requirements of Chapters 1 through 10.

22.2 Reserved.

22.3 Reserved.

22.4 Reserved.

22.5 Hazard Identification.

22.5.1 Reserved.

22.5.2* Screening for Combustibility or Explosibility. The screening test in 22.5.4.1 and in 22.5.4.3 shall be conducted to determine if a metal is in combustible or explosible form.

22.5.2.1 If either of the tests produces a positive result, the material shall be considered a combustible metal.

22.5.2.2 Test results shall be documented, the AHJ shall be notified, and the test results shall be provided when requested.

22.5.2.3 Documentation of noncombustibility proven through analytical testing of combustibility and explosibility of the specific forms of these materials, as described in this chapter and acceptable to the AHJ, is required to eliminate application of this chapter.

22.5.2.4 The application of this chapter shall be in accordance with 22.5.2.4.1 through 22.5.2.4.3.

22.5.2.4.1 Only those specific forms of metals, powders, dusts, and alloys of those materials that can be documented through accepted testing, and shown in that form not to satisfy the conditions and definitions of combustibility and explosibility, shall qualify for exclusion from the requirements of this chapter. (*See 22.1.1.6 for additional information.*)

22.5.2.4.2 Wherever combustibility can be shown to exist in these materials, the full scope and requirements of this chapter shall apply.

22.5.2.4.3 Wherever the documentation necessary for compliance with 22.5.2.2 and 22.5.2.3 is lacking, the requirements of this chapter shall apply.

22.5.2.5* Test samples for the preliminary screening tests shall be tested in forms that reflect actual process conditions. Variations in process and material conditions shall be assessed and documented in the selection of test sample materials.

22.5.2.5.1 Representative samples shall be collected from the process and preserved in suitable inert gas or vacuum packaging until tested.

22.5.2.6 Forms of combustible metal dust (CMD) that have been evaluated as noncombustible shall be required to be re-

evaluated whenever a change in manufacture, processing, handling, or storage conditions creates a modified form that might exhibit the characteristic of combustibility.

22.5.2.7* Basic Material Characterization.

22.5.2.7.1* Representative samples and components of metal-containing mixtures shall be collected and identified.

22.5.2.7.2* Collected samples, including metal-containing mixtures, shall be subject to basic materials characterization to include at a minimum composition, form, particle size and distribution, and moisture content.

22.5.2.8 Use of Test Data for Hazards Analysis.

22.5.2.8.1* The hazards analysis shall be based on data from tests of collected samples or historical data.

22.5.2.8.2* If historical data are used, an assessment of the composition, form, and particle size distribution, at a minimum, shall be compared to ensure the historical data are representative of the current material.

22.5.3 Reserved.

22.5.4 Combustibility and Explosibility Tests.

22.5.4.1 Determination of Combustibility (Fire Hazard Potential). Subsection 22.5.4.1 shall supersede 5.4.1.

22.5.4.1.1* Combustibility shall be determined for metals, metal powders, and metal dusts by the preliminary screening test set forth in Part III, Subsection 33.2.1 of the UN *Recommendations on the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria*.

22.5.4.1.1.1 Representative samples shall be maintained in suitable inert gas or vacuum packaging until tested.

22.5.4.1.2 For purposes of determining the combustibility of metal powders, pastes, finely divided materials, and metal dusts, the results of the screening test shall be categorized as one of the following three categories:

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

22.5.4.1.3 If the results of the screening test provide either no reaction or glowing but no propagation along the powder train past the heated zone by burning with flame or smoldering, the test material shall be considered to be in a noncombustible form.

22.5.4.1.4* If the material, in the form tested, ignites and propagates combustion, or ejects sparks from the heated zone after the heat source is removed, or ignites before the ignition source is applied to the sample, the material shall be considered combustible and the standard shall be applicable.

22.5.4.1.5* For materials other than dusts, powders, pastes, or other finely divided material, the flame from a 1832°F (1000°C) torch shall be applied for 10 minutes.

22.5.4.1.5.1* If the material does not sustain combustion, it shall be considered to be a metal in a noncombustible form.

22.5.4.1.5.2 Safety measures shall be taken based on the assumption that the test will result in combustion.

22.5.4.2* Determination of Flash Fire Potential. (Reserved)

22.5.4.3 Determination of Explosibility. Subsection 22.5.4.3 shall supersede 5.4.3.

22.5.4.3.1* The explosibility of metals, metal powders, metal dusts, and alloys of these materials shall be determined by using the flow chart in Figure 22.5.4.3.1.

22.5.4.3.1.1* For legacy metals, including niobium, and similar alloys or mixtures with adiabatic flame temperature higher than 3300°C, unless K_{St} and P_{max} are determined in nominal 1 m³ or larger calibrated test vessels, the K_{St} value shall be multiplied by a factor of 2 for application of the design methods in accordance with NFPA 68.

22.5.4.3.1.2* If the material is determined to be explosible, some or all of the standard test methods mentioned in Figure 22.5.4.3.1 shall be performed as needed for the hazards analysis as described in Chapter 7 and Section 22.7. If a sample either ignites during ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, screening testing prior to energizing the ignition source or results in a positive classification, it shall be considered to be explosible.

22.5.4.3.1.3 Additional tests chosen shall be those relevant to hazards analysis of the intended explosion protection techniques and flash fire hazards anticipated for the process.

22.5.4.3.2* The explosibility classification screening test shall serve as the basis to determine whether a metal, metal powder, metal dust, or alloy of these materials is capable of initiating or sustaining an explosion when suspended as a dust cloud.

22.5.4.3.3* Test samples for the explosibility classification screening tests shall be tested in forms that reflect actual process conditions and the normal composition of the material with respect to particle size distribution, moisture content, and chemical composition. Variations in process and material

conditions shall be assessed and documented in the selection of test sample materials.

22.5.4.3.3.1 Representative samples shall be maintained in suitable inert gas or vacuum packaging until tested.

22.5.4.3.4* The explosibility classification screening tests shall be conducted in accordance with ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.

22.5.5 Sampling. Sampling shall comply with Section 5.5.

22.5.6* Organometallic Materials. (Reserved)

22.6 Reserved.

22.7 Hazards Analysis. Section 22.7 shall apply in addition to the requirements in Chapter 7.

22.7.1* General Requirements.

22.7.1.1* Retroactivity. The requirements of Section 22.7 shall apply retroactively.

22.7.1.2 Solid metal in a combustible form shall meet the requirements of 22.5.2.7.

22.7.1.3 Combustible metal dusts shall meet the requirements of Section 7.2 and 22.7.2.

22.7.1.4 Molten combustible metals shall meet the requirements of 22.7.4.

22.7.1.5 The design of the fire and explosion safety provisions shall be based on a hazards analysis of the facility, the process, and the associated fire and explosion hazards.

22.7.2 Dust Hazards Analysis (DHA) Criteria.

22.7.2.1* Overview. In addition to the requirements in 7.2.1, the DHA shall also evaluate reactivity hazards associated with metal dusts.

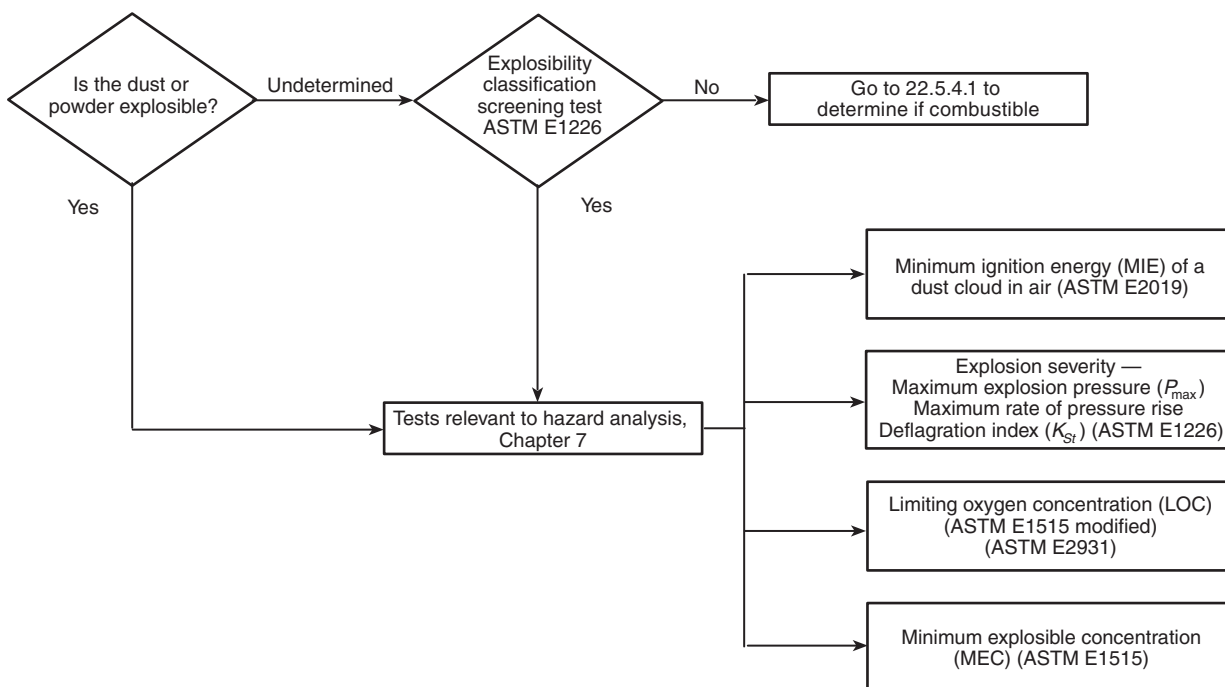


FIGURE 22.5.4.3.1 Determination of Explosibility.

22.7.2.1.1 New or altered operations, equipment, or facilities shall be reviewed for potential hazards prior to operation.

22.7.2.1.2* The design of the fire and explosion safety provisions shall be based on a hazards analysis of the facility, the process, and the associated fire and explosion hazards.

22.7.2.2 Reserved.

22.7.2.3 Documentation. The DHA shall be signed off, prior to operation, by a cognizant authority at the facility.

22.7.3 Methodology. In addition to 7.3.3.1, the evaluation shall address reactivity of the combustible metal.

22.7.4* Molten Metal Hazards Analysis Criteria.

22.7.4.1 Overview.

22.7.4.1.1 The owner/operator of a facility where combustible metals are present in a molten state shall be responsible to ensure a hazards analysis is completed in accordance with the requirements of this section.

22.7.4.1.2 For existing processes and facility compartments that are undergoing modification, the owner/operator shall complete a hazards analysis.

22.7.4.1.3 New or altered operations, equipment, or facilities shall be reviewed prior to operation for potential hazards.

22.7.4.1.4 The hazards analysis shall be reviewed and updated at least every five years.

22.7.4.1.5 The hazards analysis shall evaluate the fire, reactivity, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.2.

22.7.4.1.6 Reactivity hazards referenced in 22.7.4.1.5 shall include potential molten metal/water interactions.

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

22.7.4.2.1 Hazards analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

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

22.7.4.3.1 The results of the hazards analysis shall be maintained for the life of the process.

22.7.5 Molten Metal Hazards Analysis Methodology.

22.7.5.1 General. The hazards analysis shall include the following:

- (1) Identification and evaluation of the process or facility areas where fire, reactivity, and explosion hazards exist
- (2) Where such a hazard exists, identification and evaluation of specific fire, reactivity, 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, reactivity, deflagration, and explosion events
 - (c) Recommendation of additional safeguards where warranted, including a plan for implementation

22.7.5.1.1 Recommendations from the hazards analysis shall be tracked to completion.

22.7.5.1.2 Hazards analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

22.7.5.2 Material Evaluation.

22.7.5.2.1 The hazards analysis shall be based on data that is representative of the molten metal present.

22.7.5.3 Process Systems.

22.7.5.3.1* Each part of the process system where combustible metal in a molten form is present shall be evaluated, and the evaluation shall address the following:

- (1) Potential intended and unintended runout of combustible molten metal between parts of the process system
- (2) Potential runout of combustible molten metal from the process system into a building or building compartments, including potential interaction with water in the building or building compartments
- (3) Potential explosion impacts on other parts of the process system
- (4) Reactivity of the combustible molten metal

22.7.5.3.2 Each part of the process that contains a combustible metal in molten form 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) Combustible loading in the melting area

22.7.5.3.3* Each part of the process that contains a sufficient quantity of combustible molten metal to propagate a fire or explosion and that can potentially include all the following conditions shall be considered a fire or explosion hazard and shall be documented as such:

- (1) Oxidizing atmosphere
- (2) Combustible loading in the melting area
- (3) Water or other reactive materials in the melting area

22.7.5.4 Building or Building Compartments.

22.7.5.4.1 Each building or building compartment where combustible metal in a molten form is present shall be evaluated.

22.7.5.4.1.1 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.

22.7.5.4.1.2 The evaluation shall address potential combustible molten metal flow between buildings or building compartments.

22.7.5.4.1.3 The evaluation shall address potential fire or explosion propagation between buildings or building compartments.

22.7.5.4.2 Each building or building compartment that contains a combustible molten metal 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) Combustible loading in the melting area
- (3) Water or other reactive materials in the melting area

22.7.6 Risk Evaluation. Where a risk evaluation (*see Annex P*) is required by the AHJ, material property data and material handling and processing conditions shall be reviewed to determine the likelihood and consequences of a metal powder or dust ignition. It shall be permitted to make qualitative determinations of likelihood and consequences, providing at least some of the following property data are included in the determinations:

- (1) Minimum ignition energy (MIE)
- (2) Maximum pressure (P_{max})
- (3) Maximum rate of pressure rise (dP/dt_{max})
- (4) Deflagration index (K_{St})
- (5) Limiting oxygen concentration (LOC)
- (6) Minimum explosible concentration (MEC)
- (7) Thermal stability
- (8) Electrostatic risk
- (9) Reactivity

22.7.7 Dust Explosion and Flash Fire Hazard Areas.

22.7.7.1 Those portions of the process and facility where deflagration venting is not currently required and a dust explosion hazard or flash fire hazard exists shall be evaluated to determine appropriate protection levels from the effects of these hazards in accordance with this section and the fire protection and building construction sections in each metal section — Sections 22.16 through 22.18 — and Section 22.10.

22.7.7.2 Dust explosion hazards areas and dust flash fire hazard areas shall be deemed to exist in all operating areas of facilities processing or handling combustible metal dusts unless a hazards analysis determines otherwise.

22.8 Management Systems.

22.8.1 Reserved.

22.8.2 Reserved.

22.8.3 Reserved.

22.8.4 Housekeeping.

22.8.4.1 General.

22.8.4.1.1 Reserved.

22.8.4.1.2 Applicability. The requirements of Section 8.4 and 22.8.4 shall not apply to nanometals (*see Section 22.14*).

22.8.4.1.3 General Precautions.

22.8.4.1.3.1 Supplies of production materials in processing areas shall be limited to the amounts necessary for normal operations.

22.8.4.1.3.2 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in combustible metals processing areas unless necessary for the process and then only in designated areas.

22.8.4.1.3.3 Oil spills shall be cleaned up promptly.

22.8.4.1.3.4 Supplies shall be stored in an orderly manner with properly maintained aisles to allow routine inspection and segregation of incompatible materials.

22.8.4.1.3.5 Except for alkali metals, floor sweepings from combustible-metal-dust operations shall be permitted to contain small amounts of ordinary combustible materials.

22.8.4.1.3.6 The review of the hazards associated with cleaning operations shall include isolation, minimization, and elimination of the hazards.

22.8.4.1.3.7 In aluminum powder-handling or manufacturing buildings and in the operation of powder-conveying systems, precautions shall be taken to avoid the production of sparks from static electricity; electrical faults; impact, such as iron or steel articles on each other, on stones, or on concrete; frictional heating; or other energy sources.

22.8.4.2 Methodology.

22.8.4.2.1 Procedure.

22.8.4.2.1.1 Cleanup procedures for fugitive dust accumulations shall comply with 22.8.4.2.1.1(A) through 22.8.4.2.1.1(E).

(A)* Fugitive dust shall not be allowed to accumulate to a level that obscures the color of the surface beneath it.

(B)* It shall be permissible to establish, in a building or room, an alternate housekeeping dust accumulation threshold based on a documented hazard assessment acceptable to the AHJ.

(C) Periodic cleanup of fugitive dusts shall be accomplished by using one of the following:

- (1) Conductive, nonsparking scoops and soft brooms
- (2) Brushes that have natural fiber bristles
- (3) Dedicated vacuum cleaning systems designed for handling combustible metal powders in accordance with 22.8.4.2.2

(D) Special attention shall be paid to areas utilizing powder for accumulations in crevices and joints between walls, ceilings, and floors.

(E) Systematic cleaning of areas containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as frequently as conditions warrant.

(F) The cleaning in 22.8.4.2.1.1(E) shall include machinery.

(G) Cleaning methods shall be limited to those methods that minimize the probability of fire or explosion, as determined by a person knowledgeable in the properties of combustible-metal dusts.

(H) Chips or powder sweepings shall be removed to a designated storage or disposal area.

(I) Potential ignition sources associated with the operation of equipment during the cleaning operation shall be reviewed, and appropriate actions to isolate, eliminate, or minimize the potential hazards shall be taken.

(J) Collected dust and fines shall be removed to a safe storage or disposal area.

22.8.4.2.1.2 Cleanup of spilled dust, fine or powder shall comply with 22.8.4.2.1.2(A) through 22.8.4.2.1.2(C).

(A) Preliminary cleanup of the bulk of the spilled powder shall be accomplished by using conductive, nonsparking scoops and soft brooms as well as brushes that have natural fiber bristles.

(B) Vacuum cleaners shall be permitted to be used only for residual amounts of material remaining after preliminary cleanup.

(C) Compressed-air blowdown shall be permitted as a method for cleaning only when done in accordance with 22.8.4.2.6.

22.8.4.2.2* Vacuum Cleaning Method.

22.8.4.2.2.1 Portable Vacuum Cleaners.

(A) The use of portable vacuum cleaners shall comply with 22.8.4.2.2.

(B)* Due to the inherent hazards associated with the use of portable electrical vacuum cleaning systems, the equipment used for cleaning shall be identified for use in a Class II, Group E atmosphere. (See also 22.9.4.3.4.)

(C) Portable vacuum cleaning systems shall be effectively bonded and grounded to minimize the accumulation of static electric charge.

22.8.4.2.2.2 Vacuum cleaning systems shall be used only for the removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly removed with hand brushing.

22.8.4.2.2.3* When being used for combustible metal powder, portable vacuum cleaners shall be used only if identified for the material being vacuumed with the following conditions:

- (1) They shall be permitted only for the small amounts of residual material remaining after preliminary cleanup
- (2) They shall be emptied at the end of each operational period or shift
- (3) They shall not be used as primary dust collectors

22.8.4.2.2.4* Vacuum cleaning systems shall be effectively bonded and grounded during use to minimize the accumulation of static electric charge.

(A)* If the system is moved, grounding and bonding shall be verified.

(B) For compressed air-operated systems, the air supply hose shall comply with the manufacturer's specifications.

22.8.4.2.2.5 Vacuum cleaner hose shall be conductive or static dissipative and nozzles or fittings shall be made of conductive, nonsparking material.

22.8.4.2.2.6 Assembled components shall be conductive or static dissipative and bonded where necessary.

22.8.4.2.2.7* When a vacuum cleaner is used for other materials, the equipment shall be thoroughly cleaned prior to its use and identified accordingly.

22.8.4.2.2.8 Combustible metal dust picked up by a centralized vacuum cleaning system shall be discharged into a container located outside the building.

22.8.4.2.2.9 Sludge from dust collectors and vacuum cleaning system precipitators shall be removed weekly, as a minimum, and when equipment is shut down after use.

22.8.4.2.2.10* Portable vacuum cleaners meeting any of the following test standards shall be permitted for use in housekeeping of combustible metals in hazardous (classified) locations if their listing and manual state that they are appropriate for the combustible metals being handled:

- (1) UL 4040, *Outline of Investigation for Portable Wet-Type Dust Collectors for Collection of Combustible Metals*
- (2) BS EN 17348, *Requirements for design and testing of vacuum cleaners for use in potentially explosive atmospheres*

- (3) UL/CSA 60335-2-69, *Household and similar electrical appliances — Safety — Part 2-69: Particular requirements for wet and dry vacuum cleaners, including power brush, for commercial use*

22.8.4.2.3 Reserved.

22.8.4.2.4 Water Washdown Cleaning Method.

22.8.4.2.4.1 The use of water for cleaning shall not be permitted in manufacturing areas unless the following requirements are met:

- (1) Competent technical personnel have determined that the use of water will be the safest method of cleaning in the shortest exposure time.
- (2) Operating management has full knowledge of and has granted approval of its use.
- (3) Ventilation, either natural or forced, is available to maintain the hydrogen concentration safely below the lower flammable limit (LFL)
- (4) Complete drainage of all water effluent to a safe, contained area is available

22.8.4.2.4.2 Water-cleaning shall not be permitted in areas that have exposed alkali or water reactive materials.

22.8.4.2.4.3 Hose used for cleaning and wash down purposes shall be pressurized only while in active use for cleaning and wash down purposes.

22.8.4.2.5 Reserved.

22.8.4.2.6 Compressed Air Blowdown Method.

22.8.4.2.6.1 Compressed air blowdown shall be permitted in areas that are otherwise impossible to clean by vacuuming or other means and shall be performed under carefully controlled conditions with all potential ignition sources prohibited in or near the area and with all equipment shut down.

22.8.4.2.6.2 Vigorous sweeping or blowing down with compressed air produces dust clouds and shall be permitted only where the following requirements are met:

- (1) Prior to using compressed air, vacuum cleaning, brushing, sweeping, or water washdown methods shall be used to clean surfaces that can be safely accessed.
- (2) Dust accumulations in the area after vacuum cleaning, brushing, sweeping, or water washdown shall not exceed the threshold housekeeping dust accumulation.
- (3) Electrical equipment not suitable for Class II, Division Group E or Zone Group IIIC locations and other sources of ignition shall be shut down or removed from the area.
- (4)* Compressed air hoses shall be equipped with pressure relief nozzles limiting the discharge pressure to 30 psi (207 kPa).
- (5) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer shall be shut down or removed from the area.
- (6) After blowdown is complete, residual dust on lower surfaces shall be cleaned prior to re-introduction of potential ignition sources.

22.8.4.2.6.3 To prevent potential explosions caused by the inadvertent use of high-pressure compressed air in place of low-pressure inert gas, fittings used on outlets of compressed-air and inert-gas lines shall not be interchangeable.

22.8.4.3 Reserved.**22.8.4.4 Reserved.****22.8.4.5 Reserved.****22.8.4.6 Frequency and Goal.**

22.8.4.6.1* The accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned in daily operations shall be minimized.

22.8.4.6.2 Regular, periodic cleaning of combustible metal dust and fines from buildings and machinery including roof members, pipes, conduits, and so on, shall be carried out as frequently as conditions warrant, based on visual inspections.

22.8.4.6.3 Collected fugitive metal dust shall be removed to a designated storage or disposal area.

22.8.5* Hot Work.**22.8.5.1 Reserved.****22.8.5.2 Reserved.****22.8.5.3 Reserved.****22.8.5.4 Reserved.****22.8.5.5 Reserved.****22.8.5.6 Reserved.****22.8.5.7* Use of Portable Equipment.****22.8.6* Personal Protective Equipment (PPE).****22.8.6.1 Reserved.****22.8.6.2 Workplace Hazard Assessment.**

22.8.6.2.1 Requirements for PPE shall be based on a documented analysis of the potential for facility personnel to be exposed to hazards from combustible and molten metals during facility operations and maintenance activities.

22.8.6.2.2* The PPE hazards analysis shall determine which operations and activities warrant use of primary PPE for molten metals, primary PPE for dust flash fires, and PPE for general work and maintenance in facilities with combustible metals.

22.8.6.3* Limitations of PPE Application (Flame-Resistant Garments). (Reserved)**22.8.6.4 Reserved.****22.8.6.5 Reserved.****22.8.6.6 Primary PPE for Molten Metals.**

22.8.6.6.1 Primary PPE for molten metals shall include all of the items described in 22.8.6.6.2 to 22.8.6.6.5.

22.8.6.6.2 Face shields, neck protection, and safety glasses shall be used as part of the primary PPE for molten metal exposures.

22.8.6.6.3* External clothing, including but not limited to shirts, trousers, and coveralls, shall meet the performance requirements for primary protective clothing in ASTM F1002, *Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*.

22.8.6.6.4 Gloves or mittens shall be worn and shall be loose fitting, easily removable, and compatible with the hazards of the pertinent molten metals.

22.8.6.6.5 Protective footwear shall be high-top leather safety shoes, at least 6 in. (150 mm) high, and appropriate for the hazards of molten metals used in the areas where personnel are working.

22.8.6.7 PPE for General Work Areas Near or Containing Combustible Metals.

22.8.6.7.1 Safety glasses with side shields and hard hats shall be required as part of the PPE.

22.8.6.7.2 Outer garments worn as PPE shall be designed to prevent potential accumulations of combustible metal dust by not having exposed pockets or cuffs, and shall have a smooth outer surface that allows dust to be readily brushed off.

22.8.6.7.3 PPE shall have some measure of flame resistance determined as part of the PPE hazards analysis.

22.8.6.7.4* When worn in areas containing dusts with minimum ignition energies less than 100 mJ, PPE shall be made of static-dissipative materials.

22.8.6.7.5 PPE worn in areas containing alkali metals shall have an external clothing layer that is impervious to body moisture.

22.8.6.7.5.1* Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding firefighting personnel assigned to a combustible metal fire equipped to the requirements of NFPA 600 or NFPA 1081.

22.8.7 Inspection, Testing, and Maintenance.

22.8.7.1 An inspection, testing, and maintenance program for equipment affecting the prevention, control, and mitigation of fires, combustible dust fires, deflagrations, and explosions shall be implemented that ensures that process controls and equipment perform as designed and that a change in process or equipment does not increase the hazard.

22.8.7.2 In addition to the items in 8.7.2, the inspection, testing, and maintenance program shall include the following:

- (1) Process changes
- (2) Continuity check on grounding and bonding systems
- (3) Resistivity testing of static-dissipative footwear and conductive floors where required
- (4) Piping systems that carry or transport combustible/flamable gases, liquids, and/or hazardous chemicals, or materials that can interact and present a hazard should a release occur, (i.e., water lines in the vicinity of molten metal).

22.8.7.3 A thorough inspection of the operating area shall take place on an as-needed basis to help ensure that the equipment is in good condition and that proper work practices are being followed.

22.8.7.3.1 The inspection shall be conducted at least quarterly.

22.8.7.4 Maintenance procedures shall be reviewed annually and as required by process changes.

22.8.7.5 Document retention shall be in compliance with Section 8.13.

22.8.8 Training and Hazard Awareness.

22.8.8.1 Contractors shall also meet the requirements of 22.8.9 and Section 8.9.

22.8.8.2* General safety training and hazard awareness training for combustible metal fire hazards shall be provided to all affected employees.

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

22.8.8.3* All employees in areas handling metals in a combustible form shall be trained initially and annually in the following procedures:

- (1) All employees shall be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.
- (2) All employees shall be trained in the means of safe and proper evacuation of work areas.
- (3) All employees shall be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire-extinguishing equipment.
- (4) Employees expected to utilize fire-extinguishing equipment on incipient fires shall receive training on proper utilization of equipment.
- (5) All employees shall be taught the permissible methods for fighting incipient fires and for isolating fires and initiating an emergency notification.
- (6) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire shall be reviewed and explained.
- (7) Equipment operation, start-up and shutdown, and response to upset conditions shall be reviewed and explained.
- (8) The necessity and functioning of fire and explosion protection systems shall be reviewed and explained.
- (9) Emergency response plans shall be reviewed and explained.
- (10) The importance of housekeeping in minimizing fire and explosion hazards shall be reviewed with and explained to employees.
- (11) The appropriate cleaning and dust removal methods for the metal(s) present shall be reviewed with and explained to employees.

22.8.8.4 Personnel assigned to fire control activities shall be trained in accordance with 22.10.6.

22.8.9* **Contractors.** See Section 8.9.

22.9 Hazard Management: Mitigation and Prevention.

22.9.1 Reserved.

22.9.2 Reserved.

22.9.3 Building Design.

22.9.3.1 Reserved.

22.9.3.2 Reserved.

22.9.3.3 Reserved.

22.9.3.4 Reserved.

22.9.3.5 Reserved.

22.9.3.6* Additional Facility Design Requirements for All Metals.**22.9.3.6.1 General.**

22.9.3.6.1.1 In addition to the requirements of Section 22.9, buildings shall comply with the applicable provisions of locally adopted building and fire safety codes.

22.9.3.6.1.2 Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes if a hazards analysis is conducted to ensure the modifications do not create a greater risk.

22.9.3.6.1.3 Installation of automatic sprinkler protection, where used, shall comply with 22.9.9.5.

22.9.3.6.1.4 All enclosed passageways that can be occupied and that connect with one or more processing areas shall be provided with means of egress in accordance with local building codes.

22.9.3.6.1.5 Fuel supply lines shall have an emergency shutoff valve located within easy access outside of the building.

22.9.3.6.1.6 Emergency shutoff valves shall be clearly identified.

22.9.3.6.1.7 Fittings used on outlets of compressed air and inert gas lines shall not be interchangeable, so as to prevent potential explosions caused by inadvertently using compressed air in place of low-pressure inert gas.

22.9.3.6.1.8 One or more remotely located control stations shall be provided to allow the selective shutdown of process equipment in an emergency.

22.9.3.6.2 Building Location, Separation, and Segregation.

22.9.3.6.2.1 A hazards analysis shall be conducted to determine the minimum required separation distance for individual buildings and operations within powder, primary production, melting, recycling, and waste management facilities.

22.9.3.6.2.2 All buildings used for the processing, packing, or loading for shipment of recyclable materials shall be constructed of noncombustible materials throughout and shall have non-load-bearing walls.

22.9.3.6.2.3 All penetrations of floors, walls, ceilings, or partitions where combustible dust is present shall be dusttight, and where structural assemblies have a fire resistance rating, the seal shall maintain that rating.

22.9.3.6.2.4 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

22.9.3.6.2.5 All doors in fire-rated walls and partitions shall be listed, self-closing fire doors installed in accordance with NFPA 80.

22.9.3.6.3 Building Construction.

22.9.3.6.3.1 General. Subsection 22.9.3.6.3 shall apply to buildings or portions of buildings that are dedicated to the handling, processing, or storage of metal in combustible or molten form.

22.9.3.6.3.2 Roofs, Ceilings, and Walls.

(A)* Roof decks shall be watertight.

(B) Roofs of buildings that house combustible metal dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

(C) Walls and ceilings shall be constructed with noncombustible insulation that complies with the requirements of ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*.

(D) All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed to leave no interior or exterior voids where dust can infiltrate and accumulate.

(E) The requirements of 22.9.3.6.3.2(D) shall also apply to elevated platforms, balconies, floors, and gratings.

22.9.3.6.3.3 Floors and Surfaces.

(A) In areas where combustible metals are stored, handled, or processed, floors shall be a solid surface and shall be constructed with materials that are compatible and nonreactive with the metals in use.

(B) The floor shall be capable of providing containment of molten metals resulting from fire.

(C) Floors, elevated platforms, balconies, and gratings shall be made of noncombustible hard surfaces and nonslip materials, and shall be installed with a minimum number of joints in which powder can collect.

(D) Floors in reduction, boring, and crushing buildings shall be made of noncombustible materials, such as concrete, brick, or steel plate.

(E) Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate firefighting operations.

(F) The buildings shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

(G)* Interior surfaces where dust accumulations can occur shall be designed and constructed (and angled greater than the angle of repose) to facilitate cleaning and to minimize combustible dust accumulation.

22.9.3.6.4* Ventilation, Heating, and Cooling.

22.9.3.6.4.1 Where hydrogen generation occurs during the process, ventilation shall be provided for the dissipation of hydrogen to the atmosphere.

22.9.3.6.4.2 Mechanical ventilation systems shall be designed and installed in accordance with the locally adopted building and fire code.

22.9.3.6.4.3 Where compatible with metal processing operations, buildings shall be permitted to be heated by indirect hot-air heating systems, by bare-pipe heating systems using steam or hot water as the heat transfer medium, or by listed electric heaters.

(A) Indirect hot air shall be permitted if the heating unit is located in a combustible metal dust-free location adjacent to the room or area where heated air is required.

(B) Fans or blowers used to convey the heated or cooled air shall be located in a combustible metal dust-free location.

(C) The air supply shall be taken from outside or from a location that is free of combustible metal dust.

(D) Make-up air for building heating or cooling shall have a dew point low enough to ensure that no free moisture can condense at any point where the air is in contact with combustible metal dust or powder.

(E) The requirements of 22.9.3.6.4.3(A) through 22.9.3.6.4.3(D) shall not apply to areas where metal is melted.

22.9.3.6.5 Explosion Mitigation/Deflagration Venting.

22.9.3.6.5.1* Deflagration venting in accordance with NFPA 68 shall be required for all buildings or building areas where combustible metal powders or dusts are present, unless a hazards analysis has been performed that shows that deflagration venting is not required.

22.9.3.6.5.2 In accordance with NFPA 68, deflagration vent closures shall be directed toward a personnel-restricted area, and the vent closure shall be restrained to minimize the missile hazard to personnel and equipment.

22.9.3.6.5.3* Deflagration vents shall not be directed to any indoor area where combustible metal powders or dusts are present in quantities that present a potential fire or explosion hazard.

22.9.3.6.5.4 Equipment shall be located or arranged in a manner that minimizes combustible dust accumulation on surfaces.

22.9.3.6.5.5 Deflagration venting shall not be required for areas where combustible metal powder is stored or moved only in covered or sealed containers.

22.9.3.6.5.6* Where buildings or process areas are interconnected by enclosed passageways and there is a deflagration hazard, the passageways shall be designed to prevent propagation of an explosion or fire from one unit to another in accordance with NFPA 68.

22.9.3.6.6* Grounding and Bonding. All process equipment and all building steel shall be bonded and grounded in accordance with NFPA 70.

22.9.3.6.7 Drying Rooms. A hazards analysis shall be performed to determine the proper type of drying necessary for the specific powders being handled, as well as the specific parameters used for drying.

22.9.3.7 Additional Facility Design Requirements for Legacy Metals.**22.9.3.7.1 General.**

22.9.3.7.1.1 Individuals or firms designing facilities and/or equipment for the processing of specific combustible metal shall be briefed by individual(s) or firm(s) knowledgeable in the specific hazards associated with the manufacturing, handling, processing, and storage of the specific combustible metal and this chapter.

22.9.3.7.1.2 In addition to the requirements of Section 22.9, buildings shall comply with the applicable provisions of locally adopted building and fire safety codes.

22.9.3.7.1.3 Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes if a hazards analysis is conducted to ensure the modifications do not create a greater risk.

22.9.3.7.2 Building Location, Separation, and Segregation.

22.9.3.7.2.1 Separate buildings shall be required where different operations, including, but not limited to, atomization, grinding, crushing, screening, blending, or packaging, are performed.

22.9.3.7.2.2 More than one operation within the same building shall be permitted if the design provides equivalent protection.

22.9.3.7.2.3 Different production operations, including drying rooms, shall be located in separate but not adjoining buildings that are located at least 50 ft (15 m) from each other.

22.9.3.7.2.4 Two buildings less than 50 ft (15 m) apart shall be permitted if the wall facing the exposed building is capable of resisting a blast with a gauge pressure of 2.0 psi (13.8 kPa) and is non-load-bearing, noncombustible, and without openings.

22.9.3.7.2.5 A combustible metal powder production plant shall be located on a site large enough that the buildings in which powder is manufactured are at least 300 ft (90.9 m) from public roads and from any occupied structure, such as public buildings, dwellings, and business or manufacturing establishments, other than those buildings that are a part of the combustible metal powder production plant.

22.9.3.7.2.6 Interior walls erected for the purpose of limiting fire spread shall have a minimum 1-hour fire resistance rating and shall be designed in accordance with NFPA 221.

22.9.3.7.2.7 Sealing of penetrations shall not be required when the penetrated barrier is provided for reasons other than to limit the migration of dusts or to control the spread of fire or explosion.

22.9.3.7.3 Separation from Water.

22.9.3.7.3.1 Combustible metal winning, refining, and casting operations shall be protected from rain and other possible sources of inadvertent contact with water.

22.9.3.7.3.2 Water leakage inside or into any building where the water can contact water-reactive combustible metal shall be prevented.

22.9.3.7.3.3* Water pipes or pipes that can contain water for uses other than process or production support (e.g., sprinkler piping, domestic water pipes, roof drains, and waste pipes) shall not be permitted in areas containing combustible metals unless a hazards analysis is performed.

22.9.3.7.3.4 Piping permitted by 22.9.3.7.3.3 shall be equipped with an emergency shutoff that is identified and located outside the area.

22.9.3.7.3.5 Sprinkler systems installed in accordance with NFPA 13 shall be permitted in areas where combustibles other than combustible metals create a more severe hazard than the combustible metals and where acceptable to an authority having jurisdiction that is knowledgeable of the hazards associated with the combustible metal.

22.9.4* Equipment Design.

22.9.4.1 Reserved.

22.9.4.2 Reserved.

22.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

22.9.4.3.1 General Requirements. Paragraphs 22.9.4.3.3.15, 22.9.4.4.2.6, 22.9.4.4.2.12, 22.9.4.4.2.14(C) through 22.9.4.4.2.14(H), 22.9.4.4.3.9, and 22.8.4.2.2.1 shall be applied retroactively.

22.9.4.3.2 Specific Requirements for Pneumatic Conveying Systems.

22.9.4.3.2.1 Ductwork, Piping, and Tubing for Pneumatic Conveying Systems.

(A) Conveyor ductwork, piping, and tubing shall be fabricated of spark-resistant metals that are compatible with the metal being transported.

(B) Nonconductive ducts or duct liners, including plastics, shall not be used.

(C)* Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge.

(D)* Where the conveying duct is exposed to weather or moisture, it shall be moisture-tight.

22.9.4.3.2.2 Conveying Using an Inert Medium.

(A)* Inert gas-conveying systems shall be permitted if designed in accordance with NFPA 69.

(B) The inert gas used shall not react with the specific metal.

(C)* The concentration of oxygen in the inert gas stream shall be below the limiting oxygen concentration (LOC) of the specific gas in accordance with NFPA 69.

(D)* A residual level of oxygen below the LOC shall be present in the inert gas stream unless the conveyed material will not be exposed to air in future handling.

(E) The oxygen concentration of the inert gas stream shall be monitored in accordance with NFPA 69.

(F)* The inert gas shall have a dew point so that no free moisture can condense or accumulate at any point in the system.

(G)* If the conveying gas is inducted into the system in a relatively warm environment and the ducts and collectors are relatively cold, the ducts and collectors shall be either insulated or provided with heating so that the gas temperature does not fall below the dew point, causing condensation.

(H)* A minimum conveying velocity shall be maintained throughout the conveying system to prevent the accumulation of dust at any point and to pick up any dust or powder that drops out during an unscheduled system stoppage.

22.9.4.3.3* Specific Requirements for Dust Collection Systems.

22.9.4.3.3.1* Dust collection systems for machining, fabrication, finishing, mechanical conveying, additive manufacturing, and other dust generation operations for metals in a combustible form shall comply with the requirements of 22.9.4.3.

22.9.4.3.3.2 Powder conveying and collection for combustible metal powder production operations shall follow the requirements of 22.9.4.3.2, 22.9.4.4.2, and 22.9.4.4.3 for wet and dry AMS.

22.9.4.3.3.3 All dust collection systems shall be installed in accordance with NFPA 91.

22.9.4.3.3.4 Dust collection systems shall not be used to collect incompatible materials or other materials that might react with the conveyed metal dusts or particles.

(A) The collection of any metal other than the metal the system was designed to collect shall be prohibited.

(B) If other materials are to be collected, the modified process shall first be reviewed under management of change (MOC) to ensure that the requirements of Section 22.9 are maintained.

22.9.4.3.3.5* All dust sources (i.e., hoods) shall be connected using only a tapered main design.

22.9.4.3.3.6* Dust collection systems that remove material from operations that generate sparks, hot material, or similar ignition sources under normal operating conditions shall utilize a wet-type AMS unless protected from explosion, fire, and sparks and isolated to prevent the propagation of flame and pressure between interconnected equipment and upstream work areas in accordance with 9.8.2, 22.9.8.2, NFPA 68, and NFPA 69.

22.9.4.3.3.7* See 9.4.3.3.7.

22.9.4.3.3.8* All dust collection systems for combustible metal dusts shall have the AMD located on the clean side of the AMS.

22.9.4.3.3.9* Control panels and related equipment for controlling the operation of the AMS, AMD, monitoring equipment, or a combination thereof shall be installed in a location that is safe from the effects of a deflagration in the AMS.

22.9.4.3.3.10* The dust loading (i.e., grain loading) in ductwork during normal operating conditions shall be held below the minimum explosible concentration (MEC) in accordance with the deflagration prevention by combustible concentration reduction methods in NFPA 69.

22.9.4.3.3.11* The dry-type AMS and upstream work stations shall include a data plate listing the type of combustible metal dust that the system is designed to collect and a visible warning label that states collecting other materials can create a fire or explosion hazard.

22.9.4.3.3.12 The data plate on the dry-type AMS required by 22.9.4.3.3.11 shall include the following information:

- (1) The metal collected by the AMS
- (2) The maximum P_{max} and K_{St} of dust that can be collected by the AMS
- (3) The lowest value of minimum ignition energy of the dust that can be collected by the AMS
- (4) Where filter media is used, the specifications of the filters that must be used

22.9.4.3.3.13* A means shall be provided to prevent condensation in the ductwork.

22.9.4.3.3.14* Prevention of ignition due to static discharge shall be in accordance with 9.6.6.1 in addition to the requirements of Section 22.9.

22.9.4.3.3.15 Bonding and Grounding.

(A)* All components of dust collection systems shall be bonded and grounded independently of the electrical grounding system to minimize accumulation of static electric charge.

(B) When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

(C)* The owner/operator shall verify and document the continuity of the bonding and grounding of the dust collection system on at least an annual basis.

22.9.4.3.4* Specific Requirements for Centralized Vacuum Cleaning Systems.

22.9.4.3.4.1* The system shall be designed and maintained to ensure that the air-and-material velocity in the tubing, piping network, or both meets or exceeds the minimum required to keep the interior surfaces free of accumulations under all normal operational modes.

22.9.4.3.4.2* Vacuum cleaning tools shall be constructed of metal or shall be static dissipative and provide proper grounding and bonding to the hose.

22.9.4.3.4.3 Centralized vacuum cleaning systems shall be used only for removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly cleaned by hand brushing.

22.9.4.3.4.4* The entire centralized vacuum cleaning system shall be effectively bonded and grounded to minimize the accumulation of static electrical charge.

22.9.4.3.4.5* The tubing, piping, or both used in the system shall be metal and properly grounded and bonded.

22.9.4.3.4.6* The dry or wet AMS used in the system must comply with the requirements for dust collectors found in 22.9.4.4.2 for dry-type AMS and 22.9.4.4.3 for wet-type AMS.

22.9.4.3.4.7* The method of collected material discharge from a dry-type AMS shall be designed specifically for continuous discharge and for the characteristics of the combustible metal dust vacuumed into the system.

22.9.4.3.5* Specific Requirements for Powder Collection.

22.9.4.3.5.1 Repairs.

(A) Where repairs on dry-type collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed.

(B)* Ductwork leading into the collector shall be disconnected and isolated by blanking before repair work is permitted to be started.

22.9.4.3.5.2 High-Temperature Warning.

(A) Cyclone or other dry-type collectors shall be equipped with instruments for recording the surface temperature.

(B) An overheating alarm or warning device shall be included, and the limit setting shall be below the maximum service temperature of the filter medium or 90°F (50°C) below the ignition temperature of the powder cloud, whichever is lower.

(C) The devices specified in 22.9.4.3.5.2(B) shall give audible and visual alarms at normally attended locations.

22.9.4.3.5.3* Collector Filter Media. Collector filter media made from synthetic fabrics that accumulate static electric charges shall not be used.

22.9.4.4 AMS.

22.9.4.4.1 Reserved.

22.9.4.4.2* Dry AMS.

22.9.4.4.2.1* Dry-type filter media AMS shall not be used for metal dusts being collected in air with a K_{St} greater than 150 bar-m/s or for niobium, tantalum, titanium, zirconium, and hafnium unless their use is supported by a risk assessment that is acceptable to the AHJ.

22.9.4.4.2.2 Media dust collectors shall be provided with all the following ignition prevention measures:

- (1)* Where conductive combustible dusts having an MIE less than 30 mJ are handled, the filter media shall be static-dissipative and shall be effectively bonded to the conductive filter frame unless supported by a risk assessment that includes an evaluation of filter electrostatic charge accumulation and the electrostatic discharge ignition properties of the collected dust.
- (2)* Accumulation levels during the operation shall be monitored across the media using a pressure drop or equivalent sensor. If the accumulation exceeds the predetermined limits, a controlled shutdown of the collector and dust generation equipment shall be implemented.
- (3) Periodic inspections and the replacement of media shall be based on intervals determined by the pressure drop across the filter media or via indication of self-heating detection equipment based on oxidative self-heating and moisture reactivity.

22.9.4.4.2.3* The ingress, accumulation, or condensation of water in a dry-type AMS shall be prevented.

22.9.4.4.2.4 Dry-Type AMS Limitations.

- (A)* Electrostatic collectors shall be prohibited.
- (B) Enclosureless dry-type AMS shall be prohibited.
- (C)* Self-contained, dry-type AMS, downdraft benches, and environmental control booths with integral filter media in the wall shall be prohibited unless complying with 22.9.4.4.2.4(D).
- (D)* Self-contained, dry-type AMS, downdraft benches, and environmental control booths with integral filter media in the wall shall be permitted where a DHA has been performed and less than 0.5 lb (0.22 kg) of dust less than 500 μm is contained in the collector at any given time.
- (E) Dry-type collectors shall be located outside in a safe location and shall be provided with barriers or other means of protection for personnel.
- (F)* Collector enclosures shall be constructed of metal.

22.9.4.4.2.5* The accumulation of material inside any area of the dry-type AMS other than the discharge containers designed for that purpose and for normal operation of the AMS shall not be permitted.

22.9.4.4.2.6 Repairs.

(A) Where repairs on dry-type AMS are necessary, the AMS shall be emptied and residual accumulations of dust thoroughly removed before the repairs are made.

(B) Ductwork leading into the AMS shall be disconnected and blanked off before repair work shall be permitted to be started.

22.9.4.4.2.7 Cyclone Construction.

(A) Cyclone dry-type AMS shall be of conductive nonsparking construction suitable for the service intended.

(B)* Cyclone dry-type AMS shall be constructed with smooth internal seams to minimize material accumulation.

22.9.4.4.2.8 Temperature Monitoring Requirements.

(A)* Dry-type AMS shall be equipped with fire detection and alarm devices.

(B) The detection device shall interlock and deenergize the system and provide an audible and visual alarm at normally attended stations.

(C) Where the AMS contains filter media, detection shall be designed so that all filter locations are monitored.

22.9.4.4.2.9* Removal and replacement of filter media containing combustible dust shall be performed based on a standardized procedure that addresses the hazard of the combustible dust, work methods, and personal protective equipment.

22.9.4.4.2.10 Filter Media Properties.

(A)* Cartridge filters shall not be used with pyrophoric metal dusts.

(B) Filter media shall not be chemically reactive with the collected dust, including any contaminants carried in the dust stream with the combustible metal.

22.9.4.4.2.11 Explosion Protection.

(A) Where provided, explosion protection shall be directed to a safe location away from areas where personnel are normally present.

(B) Deflagration vents shall be positioned so that a potential blast is not directed toward any combustible or frangible structure.

(C)* Collectors shall be protected by a minimum of one of the following explosion protection methods:

- (1)* Deflagration venting in accordance with NFPA 68, which includes the following requirements:
 - (a) Where deflagration venting is used on indoor dust collectors, the vents shall be ducted to the outside and the flow resistance shall be included in the vent design.
 - (b)* Vent ducts shall be designed to prevent accumulation of moisture.
- (2)* Oxidant concentration reduction in accordance with NFPA 69, which includes the requirement to maintain a minimum concentration of oxygen to control pyrophoricity depending on the chemical properties of the material being conveyed
- (3) Deflagration pressure containment in accordance with NFPA 69

- (4)* Deflagration suppression in accordance with NFPA 69, where the suppressant has been shown to be chemically compatible and effective with the material collected
- (5)* Dilution with a compatible, noncombustible material to render the mixture noncombustible
- (6)* Deflagration venting through a listed dust retention and flame-arresting device that has been shown to be effective with the metal being collected through independent third-party testing

(D) If the method in 22.9.4.4.2.11(C)(5) is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction.

(E) Where an explosion hazard exists and is not protected by 22.9.4.4.2.11(C)(2) or 22.9.4.4.2.11(C)(5), isolation devices that have been shown to be compatible and effective with the material collected shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

(F)* Explosion isolation shall be provided in accordance with NFPA 69 between the dust collector and upstream process.

(G) Where explosion isolation is not provided, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine alternate protection methods.

(H) The selection of the type and location of vents or weak sections of the collector shall be designed to minimize injury to personnel and to minimize blast and fire damage to nearby equipment or structures.

(I) Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

(J) Signage shall be posted near the dust collector that reads, at a minimum, the following,

CAUTION:

THIS DUST COLLECTOR CAN CONTAIN EXPLOSIBLE DUST.

KEEP OUTSIDE THE MARKED AREA WHILE EQUIPMENT IS OPERATING.

(K) Where collectors are provided with deflagration vents, vent closures shall be clearly marked with, at a minimum, the following text:

WARNING:

EXPLOSION RELIEF DEVICE

22.9.4.4.2.12 Collected Material.

(A)* Discharge containers for collectors shall be emptied before or when 100 percent of the storage capacity of the container is attained, or more frequently as documented by the DHA.

(B) Material removed from the collector shall be permitted to be recycled into a process or mixed with an inert material in a volume ratio of five parts inert material to one part metal dust and, once mixed, shall be recycled or disposed of in accordance with local, state, and federal regulations.

(C) Precautions shall be taken to avoid creating dust clouds when removing dust from the collectors.

(D) The dust removed shall be recycled or disposed of in accordance with local, state, and federal regulations.

(E) The dust shall be discharged into metal containers that shall be promptly and tightly covered to avoid the creation of airborne fugitive dust.

22.9.4.4.2.13 Requirements for the Clean Air Exhaust. See 22.9.4.4.6.

22.9.4.4.2.14* Indoor Dry-Type Air-Material Separator (AMS). All portions of 22.9.4.4.2 on dry-type AMS requirements shall apply to indoor dry-type AMS in addition to this section.

(A) A hazards analysis shall be conducted in accordance with 22.5.2.7, Chapter 7, and Section 22.7 to ensure that the risk to personnel and operations is minimized for both new and existing systems.

(B) The collector shall be designed to comply with all applicable requirements in Section 22.9.

(C) The requirements for fire protection for indoor dry-type dust collection systems shall apply retroactively.

(D) An automatic fixed fire suppression system shall be provided with a fire extinguishing agent that has been shown to be effective with the material collected for indoor collectors.

(E) An automatic fixed fire suppression system shall not be required where the amount of material collected is less than 1 lb (0.45 kg) combustible metal and the dust collector is emptied after each day of operation.

(F) Collected material shall not be stored in the collector, but shall be continually emptied from the collector into a sealed metal container through an isolation device in accordance with NFPA 69.

(G) The collection of materials other than iron or steel dust shall be prohibited in collectors with a dirty volume greater than 20 ft³ (0.57 m³) or an airflow greater than 1500 ft³/min (2549 m³/hr).

(H)* Media collectors shall contain a filter break (i.e., broken-bag) detection system that automatically shuts down the collector and connected equipment if a filter break is detected.

(I)* Exhaust ducts from the fan discharge exiting the building shall be as straight and short as is practicable.

(J)* The collector inlet duct, exhaust duct, and blower shall be inspected at least every 6 months to ensure that material is not accumulating.

(K) The exhaust duct from an AMS located inside the building that traverses the building and discharges outside shall be protected by one of the following deflagration protection methods:

- (1) Deflagration pressure containment in accordance with NFPA 69
- (2)* Deflagration isolation in accordance with NFPA 69

(L)* If the material meets either of the following criteria, the additional requirements in 22.9.4.4.2.14(M), 22.9.4.4.2.14(N), and 22.9.4.4.2.14(O) apply:

- (1) The material is a UN Class 4.3 solid as tested using UN 4.3 water reactivity test methods.
- (2)* Water has not been shown to be an effective extinguishing agent (*see Table A.22.9.9.3*).

(M)* Media collectors shall include automatic cleaning of filters, and the pressure drop across the filter shall be continuously monitored and alarms activated if the pressure is outside of established operating ranges.

(N) The collector shall contain a warning sign stating the following:

**THIS COLLECTOR CONTAINS COMBUSTIBLE METAL
DUST.**

DO NOT EXTINGUISH WITH WATER.

(O) The emergency response plan required in 22.10.2 shall include the following information to emergency responders:

- (1) Location of indoor dry-type dust collectors
- (2) Direction that the collector is not to be opened to extinguish a fire
- (3)* Direction that a fire in the collector is not to be extinguished with water
- (4) A description of the automatic fire extinguishing system on the collector
- (5) A list of effective extinguishing agents for the material being collected in the collector

(P) Indoor dry-type dust collectors shall be permitted for legacy metals covered by Section 22.17, provided that one of following provisions are met:

- (1) The maximum amount of metal in a combustible form accumulating in the collector receptacle shall not exceed a maximum accumulation of 10 lb (4.5 kg) of material greater than 500 μm with a maximum of 1 lb (0.45 kg) of material less than 500 μm for an aggregate of 11 lb (5 kg) total.
- (2) The AMS has a dirty volume less than 8 ft³ (0.2 m³) or an airflow less than (500 ft³/min (850 m³/hr), and the discharge container is emptied in accordance with 22.9.4.4.2.12.

(Q) Indoor dry-type dust collectors shall be permitted for metals covered by Section 22.18, meeting the following requirements:

- (1) The P_{max} is less than 8 bar-g as measured using the test method in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*.
- (2) The K_{St} is less than 150 bar-m/s as measured using the test method in ASTM E1226.
- (3) The minimum ignition energy (MIE) is greater than 100 mJ as measured using the test method in ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.
- (4) The material is not a UN Class 4.2 solid as tested using UN 4.2 self-heating test methods.
- (5) The collection of materials other than iron or steel dust is prohibited in collectors with a dirty volume greater than 20 ft³ (0.57 m³) or an airflow greater than 1500 ft³/min (2549 m³/hr).

(R) Where an entire dust collection and AMS system, including the material collection container, is protected from fire and explosion in accordance with 22.9.4.4.2.11(C)(2), the quantity of collected material shall be permitted to be increased to 500 lb (227 kg), or a value documented by a DHA.

22.9.4.4.2.15* Portable Indoor Dry-Type Air-Material Separators (AMS) (Dust Collectors).

(A) Individual machines with portable dry dust-collection capabilities shall be permitted to be used indoors when the object being processed or finished is incapable of being moved to a properly arranged fixed hood or enclosure and shall incorporate the safeguards in 22.9.4.4.2.15.

(B) Portable indoor dry-type dust collectors shall not be connected to a permanent fixed piping system.

(C) The operation of portable dry dust-collection devices shall be subject to a DHA to ensure that the risk to personnel and operations from flash fire and shrapnel is minimized.

(D)* The portable dust collector shall not be used in an identified deflagration hazard area until appropriate housekeeping methods in Section 8.4 and 22.8.4 have been used to remove hazardous quantities of dust.

(E)* Portable dry AMS with a dirty side volume less than or equal to 8 ft³ (0.2 m³) shall not be required to be protected against explosion in accordance with NFPA 69.

(F) Personal protective clothing shall comply with 22.8.6.

(G) Prior to a change in the collected materials, the portable dry-type AMS and all associated components shall be thoroughly cleaned.

(H) Grounding of personnel operating portable indoor dust collectors shall comply with 9.6.6.3 and 22.9.6.6.3.

(I) The AMS and any associated components shall be bonded and grounded to an earth ground.

(J) Hazards associated with static discharge shall be mitigated in accordance with 9.6.6 and 22.9.6.6.

(K) Hoses shall be appropriate for use and be static dissipative or conductive.

(L)* Hoses and nozzles shall be bonded and grounded, and a path to ground shall be verified prior to use after each movement, each new connection, or both.

(M) The resistance of the path to ground shall be documented and maintained.

(N)* The material collected shall be limited to 2.2 kg (5 lb) and, at a minimum, emptied daily.

(O) The collector shall not be used on processes generating hot embers or sparks.

22.9.4.4.2.16 Operations Generating Hot Particles.

(A)* Grinding, sanding, polishing, cutting/sawing, plasma spray, or other operations generating hot metal particles shall have a spark arrester system upstream of the AMS.

(B)* Dust collection systems for hot metallic nanoparticles shall be inerted unless combustibility testing of nanoparticle dust samples demonstrate that the particles are not pyrophoric.

(C)* Ordinary combustibles shall not be allowed to enter dust collection systems using dry-type AMS collecting hot metal particles.

(D) Metal temperatures at the dust collector shall be compatible with the limiting temperature of the filter media.

22.9.4.4.3* Wet AMS.

22.9.4.4.3.1 The exhaust vent shall terminate to a safe location outside the building and shall be securely fastened except as provided in 22.9.4.4.3.3.

22.9.4.4.3.2 The clean air shall not be permitted to be returned to an identified deflagration hazard area.

22.9.4.4.3.3 The cleaned air shall be permitted to be returned to the indoor work area when tests conducted prove that the collector's efficiency is great enough to provide, to both personnel and property, safety in the particular installation with regard to particulate matter in the cleaned air and accumulations of particulate matter and hydrogen in the work area.

22.9.4.4.3.4 The exhaust duct shall be as short and straight as is practical and shall be designed to withstand the same explosion pressure as the wet-type dust collector.

22.9.4.4.3.5* The outlet portion of the AMS and the exhaust vent duct shall be inspected and cleaned as required to prevent buildup of deposits of combustible metal dusts on the interior surfaces.

22.9.4.4.3.6* The wet-type AMS shall meet or exceed the design efficiency of combustible dust collection at all times during normal operation.

22.9.4.4.3.7 The use of additional dry filter media either downstream or combined with a wet collector shall not be permitted.

(A) Where required to meet industrial hygiene exposure, dry filter media shall be permitted to be located downstream of the wet-type collector when equipped with all of the following:

- (1) Signs posted in the area warning of the hazards associated with the use of dry filter media
- (2) A differential pressure alarm
- (3) Static dissipative or conductive filter media
- (4) A means to limit hydrogen accumulation to 10 percent of the LFL
- (5) A high-temperature alarm at the filter media limit

22.9.4.4.3.8 Operational Safeguards.

(A)* The power supply to the dust-producing equipment shall be interlocked with the drive motor of the exhaust blower and the liquid-level, liquid-supply rate controller of the wet-type AMS, or both, to ensure that the system will shut down the equipment it serves if improper system function is detected.

(B) A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent the start of the dust-producing process until the wet-type AMS and AMD are fully operational.

(C) An interlock shall be provided to prevent operation of the wet-type AMS unless water tank capacity and water supply is maintained.

(D) The AMS shall be constructed of conductive materials or be static dissipative.

22.9.4.4.3.9* Disposal of Sludge from Water-Based Wet-Type Air-Material Separators.

(A)* All sludge removed from wet-type AMS shall be collected and transported in covered, vented metal containers and removed daily, at a minimum, to a safe outdoor storage or ventilated disposal area.

(B) Sludge from wet-type AMS shall be managed prior to disposal and recycled or disposed of in accordance with applicable federal, state, and local regulations.

(C) Material removed from wet-type AMS shall be permitted to be mixed with an inert material (e.g., sand or material that is nonreactive with the combustible metal) in a volume ratio of at least five parts inert material to one part metal dust.

(D) Smoking or open flames shall be prohibited in the disposal area and throughout the disposal process.

(E) Open storage of sludge from wet-type AMS shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

(F) Sludge level buildup in the sludge tank of the wet-type AMS shall not exceed 5 percent of the tank liquid capacity as measured by volume.

22.9.4.4.3.10* Requirements to Prevent the Buildup of Hydrogen in Water-Based Wet-Type Air-Material Separators.

(A) Wet-type AMS shall be designed so that hydrogen generated from the metal contacting the water is vented at all times.

(B) Vents shall remain open and unobstructed when the machine is shut down.

(C) When the AMS is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

(D) Each chamber of the AMS shall be vented to dissipate the hydrogen.

(E) Sludge shall be removed from the AMS whenever the AMS is to remain inoperative for a period of 24 hours or more.

22.9.4.4.3.11 Additional Requirements for Water-Based Wet-Type AMS.

(A) Where approved, the buildup of hydrogen in portable collectors shall be permitted to be mitigated through the use of an unimpeded vent in lieu of an auxiliary blower.

(B) Hydrogen vents shall remain open and unobstructed when the machine is shut down.

(C) When the dust collector is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

(D) Hydrogen shall be permitted to be vented indoors where the DHA documents that this activity is acceptable and considers the effects of hydrogen buildup within the building.

(E) Each chamber of the collector shall be vented to dissipate the hydrogen.

22.9.4.4.3.12 Additional Requirements for Non-Water-Based Wet-Type AMS.

(A) The liquid used shall be limited to nonaqueous Class IIIB [flash point $\geq 200^{\circ}\text{F}$ (93°C)] or noncombustible liquids.

(B) Possible vapor generation due to metal reaction with the liquid shall be evaluated and addressed as part of the DHA required in Chapter 7 and Section 22.7.

(C) Class IIIB [flash point $\geq 200^{\circ}\text{F}$ (93°C)] liquids shall be handled in accordance with NFPA 30.

(D) Pressurized transfer of liquid shall be prohibited.

(E) Formation of liquid residue in the vicinity of the operating unit shall be minimized.

22.9.4.4.3.13 Portable Indoor Wet-Type Immersion Air-Material Separators (AMS).

(A) Portable indoor wet-type immersion AMS shall comply with 22.9.4.3.3.4 through 22.9.4.3.3.4(B), and 22.9.4.4.3.10, in addition to this section.

(B) Personal protective clothing shall comply with Section 8.6.

(C) When the collector is to remain inoperative for a period of 24 hours or more, sludge shall be removed from the collector or the collector shall be permitted to be moved to an approved safe location where hydrogen venting and other hazards are sufficiently mitigated.

(D) Hoses shall be appropriate for use and be static dissipative or conductive.

(E) Hoses and nozzles shall be bonded and grounded and shall include a monitoring system to confirm appropriate bonding and grounding. A path to ground shall be verified prior to each movement, prior to each new connection, or prior to both at least daily.

(F) The maximum capacity shall not exceed 20 lb (9 kg) of sludge.

22.9.4.4.4 Enclosureless AMS. Enclosureless dry-type AMS shall be prohibited in accordance with 22.9.4.4.2.4(B).

22.9.4.4.5 AMS Locations.

22.9.4.4.5.1 Dry-type AMS shall be located outside of buildings unless permitted by 22.9.4.4.2.14.

22.9.4.4.5.2 Portable dry-type AMS located indoors shall comply with 22.9.4.4.2.15.

22.9.4.4.5.3 Portable wet-type immersion AMS located indoors shall comply with 22.9.4.4.3.13.

22.9.4.4.6* AMS Clean Air Exhaust.

22.9.4.4.6.1 Recycling of exhaust air from fixed dry-type dust collectors into buildings shall not be permitted unless all of the following requirements are met:

- (1)* The material being collected has a calculated adiabatic flame temperature below 4172°F (2300°C).
- (2) Water has been shown to be an effective extinguishing agent for the material being collected.
- (3) Combustible or flammable gases or vapors are not present either in the intake or in the recycled air in concentrations above applicable industrial hygiene exposure limits or 1 percent of the LFL, whichever is lower.
- (4)* Combustible particulate solids are not present in the recycled air in concentrations above applicable industrial hygiene exposure limits.

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

(6) Provisions are incorporated to prevent transmission of flame and pressure effects from a deflagration in an AMS back to the facility unless a risk assessment indicates that those effects do not pose a threat to the facility or the occupants.

(7) Provisions are incorporated to prevent transmission of smoke and flame from a fire in an AMS back to the facility unless a risk assessment indicates that those effects do not pose a threat to the facility or the occupants.

(8) 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.

(9) The building or room to which the recycled air is returned meets the housekeeping requirements of Section 8.4 and 22.8.4.

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

22.9.4.4.6.2 Air shall be permitted to be recirculated for materials not meeting items 22.9.4.4.6.1(1) and 22.9.4.4.6.1(2) if the AMS has a collection capacity meeting the requirements of 22.9.4.4.2.14(P).

22.9.4.5 Air-Moving Devices (Fans and Blowers).

22.9.4.6 Duct Systems.

22.9.4.6.1 All ducts and ductwork shall be constructed of metal or noncombustible conductive material.

22.9.4.6.2* Ducting runs shall be as short as practical with minimal turns.

22.9.4.6.3* Where the conveying duct is exposed to weather or moisture, it shall be moisture- and weathertight.

22.9.4.6.4* Hose and flexible connection length shall be the minimum required to accomplish the reason for their use.

22.9.4.6.5* All hoses and flex connections shall be conductive, static dissipative, or otherwise properly bonded/grounded to prevent accumulation of electrostatic charges.

22.9.4.6.6 Grinding operations shall not be served by the same dust collection system as buffing and polishing operations.

22.9.4.7 Sight Glasses. Sight glasses shall not be permitted to be used in pneumatic conveying systems for combustible metals.

22.9.4.8 Reserved.

22.9.4.9 Reserved.

22.9.4.10 Size Reduction. Size reduction shall also meet the requirements of applicable sections of this chapter.

22.9.4.11 Reserved.

22.9.4.12 Reserved.

22.9.4.13 Mechanical Feeding Devices.

22.9.4.13.1* When failure of a mechanical feeding device could cause a combustible dust hazard, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

22.9.4.13.1.1 Controls shall be provided to monitor the operation status of the equipment.

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

22.9.4.13.2.1 Belt, chain and sprocket, or other indirect drives shall be permitted when designed to stall the driving forces without slipping.

22.9.4.13.3 Mechanical feeding devices shall be capable of accepting bonding and grounding.

22.9.4.14* Bucket Elevators.

22.9.4.14.1 Casing, head and boot sections, access openings, and connecting spouts shall be as dusttight as practicable and shall be constructed of noncombustible materials.

22.9.4.14.2* Inspection openings shall be provided in the boot section to allow clean-out of the boot and inspection of the alignment of the boot pulley and belt.

22.9.4.14.3 Inspection openings shall be provided in the head section to allow complete inspection of the head pulley lagging, the belt and pulley alignment, and the discharge throat of the leg.

22.9.4.14.4* Each leg shall be independently driven by motor(s) and drive train(s) capable of handling the full-rated capacity of the elevator leg without overloading.

22.9.4.14.4.1 Multiple motor drives shall be interlocked to prevent operation of the leg upon failure of any single motor.

22.9.4.14.4.2 The drive shall be capable of starting the unchoked leg under full (100 percent) load.

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

22.9.4.14.6 The use of combustible plastic, rubber, and other combustible linings shall be limited to high-impact areas and wear surfaces as permitted by the DHA.

22.9.4.14.7 The leg head section between the up and down casings shall be sloped at an angle of not less than 45 degrees.

22.9.4.14.8 All spouts shall be designed and installed to handle the full-rated elevating capacity of the largest leg feeding such spouts.

22.9.4.14.9 Legs shall have lagging installed on the head pulley to minimize slippage.

22.9.4.14.10* Leg conveyor belts and lagging shall have a surface electrical resistivity not greater than 300 megaohms per square (3×10^8 ohms per square).

22.9.4.14.11 Leg belts and lagging shall be fire resistant and oil resistant.

22.9.4.14.11.1 Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 12.18.65, or the flame test for belting in Part 13.2 of ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*.

22.9.4.14.12* Monitors.

22.9.4.14.12.1 All head, tail, and knee pulley bearings shall have monitoring to detect high bearing temperature or vibration.

22.9.4.14.12.2 All head, tail, and knee pulleys shall have monitoring to detect belt alignment.

22.9.4.14.12.3 Abnormal conditions shall actuate a visual or an audible and visual alarm requiring corrective action.

22.9.4.14.13 Explosion Prevention/Protection. Where an explosion hazard exists, protection of bucket elevator legs shall be in accordance with Section 9.8 and 22.9.8.

22.9.4.15 Conveyors and Spouts.

22.9.4.15.1* When an enclosed conveying device could cause a combustible dust hazard, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

22.9.4.15.2* Conveyors whether enclosed, partially enclosed, or open, shall be designed to either relieve or stop if the discharge end becomes plugged.

22.9.4.15.2.1* Feed to the bulk material conveyors should be stopped, diverted, or otherwise handled in a safe manner.

22.9.4.15.3 Bulk material conveyor belts shall have belt alignment and hot bearing sensors at the head and tail.

22.9.4.15.4 Bulk material conveyor belts and lagging shall have a surface electrical resistivity not greater than 300 megaohms per square (3×10^8 ohms per square) and shall be fire resistant and oil resistant. (*See A.22.9.4.15.5.*)

22.9.4.15.4.1* Belts shall be fire and oil resistant.

22.9.4.15.5* Use of combustible lining shall be permitted as evaluated as part of the DHA, in spouts and other handling equipment at impact points and on wear surfaces.

22.9.4.15.6* Enclosed Conveyors. Explosion protection shall be provided for enclosed conveyors where an explosion hazard exists.

22.9.4.15.7 Housing and Coverings.

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

22.9.4.15.7.2 Flexible screw conveyors shall not be permitted to be used with metal dusts or powders.

22.9.4.15.7.3 The discharge spout shall be designed to prevent the accumulation of electrostatic charges.

22.9.4.16 Mixers and Blenders.

22.9.4.16.1 Mixers and blenders shall be designed to control fugitive dust emissions.

22.9.4.16.2* Foreign materials that can become ignition sources shall be prevented from entering the mixer or blender.

22.9.4.16.3 Clearance and alignment of moving parts and seals in equipment 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.

22.9.4.16.4 Mixers and blenders shall be made of metal or other noncombustible material, and compatible with the materials being mixed or blended.

22.9.4.16.5* Where an explosion or fire hazard exists, protection shall be provided.

22.9.4.17 Dryers. Drying of legacy metals shall comply with the requirements in Section 22.17.

22.9.4.17.1 Drying Media. 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.

22.9.5 Dust Control.

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

22.9.5.2 Liquid Dust Suppression Methods for Dust Control. Liquid dust suppression methods shall not be used with combustible metals unless acceptable through the DHA.

22.9.6 Ignition Source Control.

22.9.6.1* Retroactivity. Unless otherwise specified, the requirements of 22.9.6 shall be applied retroactively.

22.9.6.2 Reserved.

22.9.6.3 Reserved.

22.9.6.4 Bearings.

22.9.6.4.1 Ball or roller bearings shall be sealed against dust.

22.9.6.4.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal dust and shall have a lubrication program.

22.9.6.4.3 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

22.9.6.4.4 Localized frictional heating of bearings in any machine shall be minimized.

22.9.6.4.5 Grounded and bonded bearings shall be used.

22.9.6.4.6 Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes, a conductive lubricant, or other applicable means.

22.9.6.5* Hazardous (Classified) Locations for Electrical Installations.

22.9.6.6 Electrostatic Discharges.

22.9.6.6.1 Conductive Equipment.

22.9.6.6.1.1 Reserved.

22.9.6.6.1.2 Reserved.

22.9.6.6.1.3 Reserved.

22.9.6.6.1.4 Flexible Connectors. Flexible connectors shall comply with 22.9.6.6.7.

22.9.6.6.2 Maximum Particulate Transport Rates.

22.9.6.6.2.1* The maximum particulate transport rates in 22.9.6.6.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft³ (1 m³) 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.

22.9.6.6.2.2* The maximum particulate transport rate in 22.9.6.6.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft³ (1 m³) 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.

22.9.6.6.2.3* Where the conditions of 22.9.6.6.2.1 or 22.9.6.6.2.2 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).

22.9.6.6.3 Grounding of Personnel.

22.9.6.6.3.1* Personnel involved in manually filling or emptying containers or vessels, or handling open containers of metals in a combustible form, shall be grounded during such operations unless the conditions of 9.6.6.3.2 are met.

22.9.6.6.4 Flexible Intermediate Bulk Containers (FIBCs). FIBCs shall not be permitted to be used for the handling and storage of legacy metals except for aluminum.

22.9.6.6.5 Reserved.

22.9.6.6.6 Spark-Resistant Tools.

22.9.6.6.6.1* Where tools and utensils are used in areas handling metals in a combustible form with minimum ignition energy less than 30 mJ or in a hybrid mixture, consideration shall be given to the risks associated with generating impact sparks and static electricity.

22.9.6.6.6.2* Tools including but not limited to scoops, shovels, and scrapers, used in the handling of metals in a combustible form shall be electrically conductive, bonded, and grounded, and shall be made of spark-resistant materials.

22.9.6.6.6.3 Spark-resistant tools shall be used when repairs or adjustments are made on or around any machinery or apparatus where metals in a combustible form are present and cannot be removed.

22.9.6.6.7* General Requirements.

22.9.6.6.7.1* All permanently installed process equipment and all building structural steel shall be grounded and bonded by permanent ground wires to prevent accumulation of static electricity.

(A) Grounding and bonding of equipment shall be independent of the facility electrical system.

(B)* Where nonconductive components present a discontinuity in the electrical path, isolated conductive components shall be bonded.

22.9.6.6.7.2* Movable or mobile process equipment or tools of metal construction shall be bonded or grounded or both, prior to use.

22.9.6.6.7.3* A monitoring and testing schedule shall be established based on the requirements of Section 6.2 to ensure that the effectiveness of grounding and bonding of fixed and mobile equipment has not failed or deteriorated over time and use.

22.9.6.6.7.4 Static dissipative belts shall be used on belt-driven equipment.

22.9.6.6.7.5 Bonding and grounding for dust collection and pneumatic conveying shall be in accordance with 9.4.3 and 22.9.4.3.

22.9.6.7 Reserved.

22.9.6.8 Reserved.

22.9.6.9 Reserved.

22.9.6.10 Reserved.

22.9.6.11 Friction and Impact Sparks.

22.9.6.11.1 All machinery shall be installed and maintained in such a manner that the possibility of friction sparks is minimized.

22.9.6.11.2 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.

22.9.6.11.3 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.

22.9.6.12 Reserved.

22.9.6.13 Reserved.

22.9.6.14 Electrical Systems.

22.9.6.14.1 All electrical equipment and wiring shall be installed in accordance with *NFPA 70*.

22.9.6.14.2 All process equipment and all building steel shall be bonded and grounded in accordance with *NFPA 70*.

22.9.6.14.3 All manufacturing buildings shall be provided with emergency lighting systems in accordance with *NFPA 101*.

22.9.6.14.4 Control equipment, control rooms, and offices meeting the requirements of *NFPA 496* shall be permitted.

22.9.6.14.5 Preventive maintenance for electrical equipment shall be established commensurate with the environment and conditions.

22.9.6.14.6 One or more remotely located control stations shall be provided to allow the safe and selective shutdown of process equipment in an emergency.

22.9.6.14.7 Where process equipment presents a deflagration hazard to a normally unoccupied room or building, an interlock shall prevent process operation unless associated room doors are fully closed.

22.9.6.14.8 Where process equipment presents an internal deflagration hazard, an interlock shall prevent equipment operation unless associated access panels are fully closed.

22.9.6.15 Fans and Blowers.

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

22.9.6.15.2* Fans and blowers used to move air or inert gas in conveying ducts shall be of spark-resistant design and compatible with the material to be conveyed.

22.9.6.15.3 The design of the fan or blower shall not allow the transported combustible metal powder to pass through the fan before entering the final collector, unless the combustible metal powder-conveying system is inerted.

22.9.6.15.4* Fans or blowers shall be equipped with ball or roller bearings.

22.9.6.15.4.1 Bearings shall be equipped with temperature indicating devices.

22.9.6.15.4.2 Bearings shall be arranged to sound an alarm in case of overheating.

22.9.6.15.5 Fans and blowers shall be electrically interlocked with powder-producing machinery so that the machines can operate only if the fans are operating.

22.9.6.16* Grinding Wheels.

22.9.6.16.1 Wheels used for grinding combustible metal castings shall be relocated for dressing.

22.9.6.16.2 If it is not feasible to move the grinding wheels to a safer location for dressing, the hoods shall be thoroughly cleaned or removed entirely before dressing operations are started, and all deposits of dust on and around the wheel shall be removed before, during, and after dressing.

22.9.7 Reserved.

22.9.8 Explosion Prevention and Protection.

22.9.8.1 Reserved.

22.9.8.2* Equipment Protection. For legacy metals, including niobium, and similar alloys or mixtures with adiabatic flame temperatures higher than 3300°C, explosion protection

systems such as venting, flameless venting, suppression, and isolation systems shall be tested and certified under realistic deflagration conditions with a representative metal dust and at a test vessel volume representative of the actual application.

22.9.9 Fire Protection.

22.9.9.1 General. In addition to the requirements in 22.9.9, the requirements in Section 22.10 shall also apply.

22.9.9.2 Reserved.

22.9.9.3* Fire Extinguishers: Extinguishing Agents and Application Techniques.

22.9.9.3.1* Class D extinguishing agents or those agents shown to be effective for controlling combustible-metal fires shall be provided in areas where metals in a combustible form are present.

22.9.9.3.1.1 The effectiveness of the fire suppressing agent for controlling, suppressing, or extinguishing a fire involving a specific combustible metal shall be demonstrated to the AHJ or supported by third-party testing.

22.9.9.3.1.2 Any agent that when applied at the recommended rate results in an increase in fire intensity shall be prohibited.

22.9.9.3.2 A supply of extinguishing agent for manual application shall be kept within easy reach of personnel working with combustible metal powder.

22.9.9.3.3 Container lids shall be kept in place to prevent agent contamination and to keep agents moisture free.

22.9.9.3.4 Portable or wheeled extinguishers listed for use on combustible-metal fires shall be provided and shall be distributed in accordance with NFPA 10.

22.9.9.3.5 The following agents shall not be used as extinguishing agents on a combustible-metal fire because of adverse reactions or ineffectiveness unless they are compatible with the metal and are an effective extinguishing agent (*see* 22.9.9.3):

- (1) Water
- (2) Foams
- (3) Halon
- (4) Carbon dioxide
- (5)* Nitrogen (IG-100)
- (6) Halocarbon Clean Agents

22.9.9.3.6 A:B:C dry-chemical and B:C dry-chemical extinguishers shall not be used as an extinguishing agent on a combustible-metal fire but shall be permitted to be used on other classes of fires in the area where combustible metals are present.

22.9.9.3.7 Fire-extinguishing agent expellant gases shall be compatible with the combustible metal.

22.9.9.3.8 Where Class A, Class B, or Class C fire hazards are in the combustible-metal area, extinguishers suitable for use on such fires shall be permitted, provided they are marked "Not for Use on Combustible-Metal Fires."

22.9.9.3.9* Incipient fires in solvent-wetted powders shall be handled according to 22.9.9.3.9.1 or 22.9.9.3.9.2.

22.9.9.3.9.1 An incipient fire occurring while the metal powder is in slurry form shall be permitted to be fought using

listed Class B extinguishing agents, except that halogenated extinguishing agents shall not be used.

22.9.9.3.9.2 An incipient fire occurring in semi-wet material or filter cake shall be fought using a listed Class B extinguishing agent.

(A)* Where Class B extinguishing agents are used to extinguish fires involving solvent-wetted aluminum, the residual material shall be immediately covered with dry sand, with dry inert granular material, or with another listed Class D extinguishing agent, and the entire mass shall be allowed to cool until it reaches ambient temperature.

(B)* When the material has cooled and it has been determined that there are no hot spots, the covered material shall be carefully removed for disposal.

(C) The material shall be handled in covered containers.

22.9.9.3.10 Applications of extinguishing agents shall be handled according to 22.9.9.3.10.1 through 22.9.9.3.10.4.

22.9.9.3.10.1* An incipient fire shall be ringed with a dam of dry sand, with dry material that will not react with the metal being extinguished, or with a listed or approved Class D extinguishing powder in accordance with the manufacturer's instructions.

22.9.9.3.10.2 Application of dry extinguishing agent shall be conducted in such a manner as to avoid any disturbance of the combustible-metal dust, which could cause a dust cloud.

22.9.9.3.10.3* The use of pressurized extinguishing agents shall not be permitted on a combustible-metal powder fire or chip fire, unless applied carefully so as not to disturb or spread the combustible-metal powder or chip fire.

22.9.9.3.10.4 Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing combustible-metal fires shall be permitted in combustible metal processing locations at risk for combustible metal fires.

22.9.9.3.11 Fire-extinguishing agents compatible for the hazards present shall be available in metal-scrap storage areas.

22.9.9.3.12 Fire-extinguishing agents compatible for the hazards present shall be available in metal-powder storage areas.

22.9.9.4 Hose, Standpipes, Hydrants, and Water Supply. The requirements in 9.9.4 shall apply where water has been deemed an acceptable extinguishing agent.

22.9.9.5 Automatic Sprinklers.

22.9.9.5.1 Automatic Sprinkler Protection for Combustible Metals Other Than Alkali Metals.

22.9.9.5.1.1* Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled unless allowed by 22.9.9.5.1.2, 22.9.9.5.1.3, and 22.9.9.5.1.4.

22.9.9.5.1.2* Sprinkler systems installed in accordance with NFPA 13 shall be permitted in areas where combustibles other than combustible metals in molten form or in a state that could cause an immediate explosive reaction with water create a more severe hazard, as determined by a hazards analysis, than the metals and where acceptable to an authority having juris-

diction knowledgeable of the hazards associated with combustible metals.

22.9.9.5.1.3 The hazards analysis shall consider the possibility of fires and explosions involving both combustible metals and the other combustibles.

22.9.9.5.1.4 The special hazards associated with metals in a combustible form and in contact with water shall be considered in the selection, design, and installation of automatic sprinkler systems.

22.9.9.5.1.5 Employee training and organizational planning shall be provided to ensure safe evacuation of the areas that contain combustible metal hazards in case of fire in accordance with 22.10.5.

22.9.9.5.1.6* Light casting storage areas shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 989 ft³ (28 m³) is contained in a building of combustible construction
- (2) Where magnesium products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 30 ft (9 m) of the magnesium

22.9.9.5.2 Sprinkler Protection for Alkali Metals.

22.9.9.5.2.1* Buildings or portions of buildings in which the only combustible hazard present is alkali metals shall not be permitted to be equipped with sprinkler protection.

22.9.9.5.2.2 Buildings or portions of buildings that have combustible hazards in addition to alkali metals shall be evaluated for fire protection requirements with a hazards analysis that is acceptable to the authority having jurisdiction.

22.9.9.5.2.3 Sprinkler systems installed in accordance with NFPA 13 shall be permitted in areas where combustibles other than alkali metals create a more severe fire hazard than the alkali metals and where acceptable to an authority having jurisdiction knowledgeable of the hazards associated with alkali metals.

22.9.9.5.2.4 As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the alkali metals operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

22.9.9.5.2.5 Fire-extinguishing agents compatible for the hazards present shall be readily available in combustible metals-scrap storage areas.

22.9.9.5.2.6* Fire-extinguishing agents compatible for the hazards present shall be readily available in combustible-metals-powder storage areas.

22.10 Emergency Planning and Response.

22.10.1 Reserved.

22.10.2* Emergency Response Plan.

22.10.2.1 Local emergency response agency notification shall be required for any operation storing or processing 5 lb (2.27 kg) or more of powder, dusts, fines, or alkali metal in any form or 500 lb (227 kg) or more of chips or turnings.

22.10.2.2* Because of the unique nature of combustible-metal fires, a written emergency preparedness/response plan shall be

prepared and maintained by the facility owner or operator where combustible metals are processed, handled, used, or stored.

22.10.2.2.1 The emergency response plan shall be reviewed and validated at least annually, highlighting specific actions in the event of a combustible metal fire.

22.10.2.2.2* Clothing Fires.

22.10.2.2.2.1 Emergency procedures for handling clothing fires shall be established as part of the plan.

22.10.2.2.2.2 If deluge showers are installed, they shall be located away from dry metal powder-processing and metal powder-handling areas.

22.10.2.2.3 The plan shall address locations for remote shut-off of supply systems when any of the following are present:

- (1) Water (water from all types of sources)
- (2) Electrical materials
- (3) Flammable gases
- (4) Ignitable (flammable or combustible) liquids
- (5) Toxic materials
- (6) Other hazardous materials

22.10.2.2.4 The following information on the safe handling of combustible metal fires shall be provided for emergency preparedness planning:

- (1) Water, when applied to most burning combustible metals, results in an increase in burning intensity and possible explosion.
- (2) Water applied to alkali metals not involved in the fire will result in hazardous decomposition, ignition, or explosion.
- (3) Application of carbon dioxide on combustible-metal fire adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres. (See 22.9.9.3.)
- (4) Dry chemical extinguishers react with alkali metals and intensify the fire.
- (5) Dry chemical extinguishers utilized on non-alkali metal fires are ineffective in controlling the metal fire but might be effective where ignitable (flammable or combustible) liquids are used and the metal is not yet involved in the fire. (See 22.9.9.3.)
- (6) Halogenated extinguishing agents used on alkali metals can result in an explosion.
- (7) Halogenated extinguishing agents will have a detrimental effect on other combustible metal fires, with the decomposition producing hazardous by-products.
- (8) A primary metal fire displays intense orange-to-white flame and can be associated with a heavy or large production of white or gray smoke.
- (9) When water is applied to non-alkali combustible metal, it can disassociate to the basic compounds, oxygen and hydrogen. Similar results occur with carbon dioxide.
- (10) When water is applied to alkali metals, hydroxides and hydrogen are generated immediately.
- (11) Fires involving combustible metals that contain moisture exhibit more intense burning characteristics than dry product.
- (12) Extreme heat can be produced. For example, burning titanium and zirconium have the potential to produce temperatures in excess of 7000°F (3857°C) and 8500°F (4690°C), respectively.

- (13) Dusts, fines, and powders of combustible metals present an explosion hazard, especially in confined spaces.
 - (14) Dusts, fines, and powders of titanium and zirconium present extreme hazards; zirconium powders have ignition temperatures as low as 68°F (20°C). Static electric charges can ignite some dusts and powders of titanium and zirconium.
 - (15) Zirconium and titanium powder can exhibit pyrophoric characteristics.
 - (16) Turnings and chips of combustible metals can ignite and burn with intensity, especially if coated with a petroleum-based oil, with some spontaneous combustion having been observed.
 - (17) With the exception of alkali metals, the larger the product, the smaller the likelihood of ignition. Bars, ingots, heavy castings, and thick plates and sheets are virtually impossible to ignite and, in most cases, self-extinguish when the heat source is removed.
 - (18) The sponge product of most combustible metals burns at a slower rate but still produces tremendous heat.
 - (19) Burning combustible metals can extract moisture from concrete and similar products that can intensify burning and cause spalling and explosion of the products and spewing of chunks of concrete.
 - (20) Burning metal destroys asphalt and extracts moisture from rock.
 - (21) Most fires involving non-alkali combustible metals usually cannot be extinguished, and unless they are placed in an inert atmosphere of argon or helium, they can only be controlled.
 - (22) Fires involving large quantities of metals should be allowed to cool for at least 24 hours prior to being disturbed to prevent re-ignition.
 - (23) Fires will oxidize most metals and provide a protective covering limiting open burning.
 - (24) Alkali metal fires can be extinguished with the suitable extinguishing agents correctly applied. (*See 22.9.9.3.*)
 - (25) Combustible metal fines and powders that are stored and contain moisture can produce hydrogen gas.
 - (26) Combustible metal fines and dusts that are reduced (not oxidized) and that come into contact with other metal oxides can result in thermite reactions.
- 22.10.2.3** Prior to the arrival of alkali metals on site, the local fire department shall be notified of the presence of water-reactive materials on site and shall be notified of the hazards of using water on alkali-metal fires.
- 22.10.2.4** Where combustible metal is collected or stored in containers, material-handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.
- 22.10.2.5** The following list of actions to be performed as well as information regarding the hazards of combustible metals shall be provided to emergency responders for the safe handling of combustible metal fires:
- (1)* Perform a size-up, evaluation, and identification of metals involved in the fire.
 - (2) Ensure control of utilities (e.g., water, gases, power, etc.) to affected areas.
 - (3) Review safety data sheets (SDSs) for the involved products, and if available, contact those familiar with the product and hazards.
 - (4) Evaluate whether the fire can be isolated safely and allowed to burn out.
 - (5) Determine whether uninvolved product and exposures — other than alkali metals — can be protected by hose streams, after an adequate review has been completed to ensure any runoff from hose streams does not come into contact with burning or molten combustible metal.
 - (6) Do not apply water to alkali metals in either a fire or nonfire situation.
 - (7) Use an inert blanket, such as argon, helium, or nitrogen, if the fire is burning in a closed container, such as a dust collection system, to control the fire where an adequate delivery system is available and personnel safety is considered.
 - (8) Evaluate the potential for explosion.
 - (9) Use extreme caution with fires involving combustible-metal powders, dusts, and fines because of the possibility of explosions, especially if the product becomes airborne and there is an available ignition source.
 - (10) Evaluate the control and shutdown of both domestic and fire protection water systems to prevent unintended contact of water with burning or molten combustible metal.
 - (11) Use extinguishing agents that are compatible with the hazards present. (*See 22.9.9.3.*)
 - (12) Use extinguishing agents for containment of small and incipient fires. (*See 22.9.9.3.*)
 - (13)* Use extreme caution with fires involving large quantities of product within structures.
 - (14) Most fires involving combustible metals cannot be extinguished in a manner other than by providing an inert atmosphere of argon or helium — and nitrogen for alkali metals or iron — if the product is dry.
 - (15) Most fires can be controlled by application of argon or helium — or nitrogen for alkali metals or iron — or by the development of an oxide crust.
 - (16) The temperature of the metals involved in the fire can remain extremely high and the fire can flare up again if the product is disturbed prior to complete oxidation of the product or self-extinguishment.
 - (17) Water in contact with molten combustible metals will result in violent steam explosions, and can cause hydrogen explosions and reactions.
 - (18) Isolate the metal as much as possible; large fires might be impossible to extinguish.
 - (19) Evaluate whether there is adequate drainage to prevent the contact of water with burning metal that is not compatible for protecting exposures.
 - (20) Evaluate the fire to determine whether the fire can burn itself out naturally to minimize hazards to personnel and losses to exposures.

22.10.3 Reserved.

22.10.4 Fire Prevention.

22.10.4.1 Control of Combustible Materials.

22.10.4.1.1 Areas in which ignitable (flammable and combustible) liquids are used shall be in accordance with the requirements of NFPA 30.

22.10.4.1.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 50 gal (189 L) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 200°F (93°C).

22.10.4.1.1.2 Dipping and coating applications of ignitable (flammable or combustible) liquids shall be done in accordance with NFPA 34.

22.10.4.1.1.3 Spray application of ignitable (flammable or combustible) liquids shall be done in accordance with NFPA 33.

22.10.4.1.2 Ordinary Combustible Storage.

22.10.4.1.2.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in processing areas unless necessary for the process, and then only in designated areas.

22.10.4.1.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

22.10.4.1.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

22.10.4.1.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

22.10.4.1.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

22.10.4.2* Molten Metal.

22.10.4.2.1 All containers used to receive molten metal, molten titanium, molten titanium chloride, or liquid alkali metals shall be cleaned and dried thoroughly before use.

22.10.4.2.2 All pieces of metal shall be clean and dry when charged to reactors.

22.10.5 Firefighting Activities.

22.10.5.1* Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent.

22.10.5.2 In case of fire in the chips, turnings, or powder compact, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of combustible metals, until the fire has been extinguished and the material has cooled to ambient temperature.

22.10.5.3 Combustible-metal fires beyond the incipient stage shall be fought by professional firefighters, specially trained fire brigade personnel, or both.

22.10.5.4 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residue has cooled to room temperature.

22.10.5.5 Fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

22.10.5.6 Fire residues shall be disposed of in accordance with federal, state, and local regulations.

22.10.5.7 When drums or tote bins of burning materials can be moved safely, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

22.10.5.8 Processing Equipment.

22.10.5.8.1* When a fire occurs in processing equipment, material feed to the equipment shall be stopped.

22.10.5.8.2 The equipment shall be kept in operation, unless continued operation will spread the fire.

22.10.5.9 Alkali Metals Firefighting Procedures.

22.10.5.9.1* While an alkali-metal fire is being fought, every effort shall be made to avoid splattering the burning alkali metals.

22.10.5.9.2* Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

22.10.6 Firefighting Organization.

22.10.6.1 Only trained personnel shall be permitted to engage in fire control activity.

22.10.6.1.1 Personnel other than trained personnel shall be evacuated from the area.

22.10.6.1.2 Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

22.10.6.2 Firefighting personnel shall be given training in the extinguishment of test fires set in a safe location away from manufacturing buildings.

22.10.6.2.1 Training shall include all possible contingencies.

22.10.6.2.2* If professional or volunteer firefighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by a unified incident command that includes knowledgeable plant personnel.

22.11 Reserved.

22.12 Reserved.

22.13 Reserved.

22.14 Nanometal Powders

22.14.1 Retroactivity. The requirements of Section 22.14 shall apply retroactively.

22.14.2* General.

22.14.2.1 Processing, handling, and storage of nanometal powders shall follow the requirements of Section 22.14 in addition to the fire and explosion prevention and mitigation requirements in Sections 22.10 through 22.18.

22.14.2.2* The requirements of Section 22.14 are applicable to mixtures of nanometal powder particles and micrometer-sized metal particles where the nanometal powder particles are greater than 0.1 percent by weight.

22.14.2.3 If testing with a specific mixture and particle size distribution shows that the explosibility characteristics are similar to the micrometer metal particles, the requirements of Section 22.14 do not apply.

22.14.2.4* Due to the special hazards of nanometals, a DHA conducted in accordance with Chapter 7 and Section 22.7 shall include a determination of the appropriate effective fire and

explosion protection measures for combustible metal nanoparticle processes and equipment.

22.14.3 Nanoparticle Production Processes.

22.14.3.1 Nanometal Production Using Exploding Electrical Wires.

22.14.3.1.1* Fire, flash fire, and explosion hazards associated with exploding electrical wire production of nanometals, as well as the energy associated with the exploding wires, shall be assessed and documented.

22.14.3.1.2* Fire and explosion protection measures for this process equipment shall be established based on the hazards analysis, other pertinent requirements of this chapter, and blast wave protection for the exploding wires.

22.14.3.1.3 The power supply and electrical circuits used for exploding electrical wire production shall be in accordance with *NFPA 70*.

22.14.3.1.4 If an inert gas atmosphere is used in the chamber containing the exploding wires, control of the maximum allowable oxygen concentration shall be in accordance with Chapter 7 of *NFPA 69*.

22.14.3.1.5 If a hydrogen atmosphere is used in the chamber containing the exploding wires, the generation and use of hydrogen shall be in accordance with *NFPA 2*.

22.14.3.2 Nanometal Production with Plasma-Based Processes.

22.14.3.2.1* Fire and explosion hazards associated with nanometal production by recondensation after metal immersion in a plasma, as well as the potential ignitions due to exposure to plasma thermal loads and ionized and aerosol particles, shall be assessed and documented.

22.14.3.2.1.1 Fire and explosion protection measures for this process shall be established based on the hazards analysis and the other pertinent requirements of this chapter.

22.14.3.2.2 The internal surfaces of plasma-generating equipment shall be inspected after each production run to check for combustible metal particulate condensation and accumulation, and shall be cleaned where such condensation and accumulation is observed.

22.14.3.2.3 Particulate cooling, capture, and encapsulation equipment shall be operated per requirements in 22.14.4.

22.14.3.3 Nanometal Synthesis by Chemical Reduction of Salt Solutions and Colloidal Dispersions.

22.14.3.3.1* Fire and explosion hazards associated with nanometal production by chemical reduction methods, as well as the chemical reactivity hazards and the flammability properties of all reactants and reaction products, shall be assessed and documented.

22.14.3.3.2 Fire and explosion protection measures for this process shall be established based on the hazards analysis and the other pertinent requirements of this chapter.

22.14.3.3.3* Fire protection for solutions with ignitable (flammable or combustible) liquid solvents shall be in accordance with requirements of *NFPA 30*.

22.14.3.4 Biochemical Production of Nanometals.

22.14.3.4.1* Fire and explosion hazards associated with nanometal production by biochemical processes, as well as the biochemical reactivity and flammability hazards and possible needs for biological or microbiological containment, shall be assessed and documented.

22.14.3.4.1.1 Fire and explosion protection measures for this process shall be established based on the hazards analysis and the other pertinent requirements of this chapter.

22.14.3.5* Nanoparticle Production by Thermal Spray Pyrolysis. Fire and explosion protection measures for combustible metal nanoparticle thermal spray pyrolysis production processes and equipment shall address the hazards of the materials coated by the nanoparticles, including the potential for pyrophoric reactions of the nanoparticles and coating upon suddenly being introduced to an air atmosphere.

22.14.4 Equipment Design and Operation.

22.14.4.1* Nanometal transport in pipes, ducts, and conveyors shall use an inert gas at an oxygen concentration below the limiting oxygen concentration (LOC) in accordance with *NFPA 69*. The LOC shall be measured specifically for submicron particulate of the primary metal transported.

22.14.4.2 Equipment with inerting for nanometals shall use an inert gas atmosphere in accordance with *NFPA 69* and a LOC based on testing with an applicable nanometal sample.

22.14.4.3 Explosion suppression and isolation systems for nanometal explosion protection shall be in accordance with *NFPA 69* and shall have been demonstrated to be effective for pertinent nanometals.

22.14.4.4* Equipment containing nanometals that are intended to withstand explosion pressures shall have a pressure containment capability in accordance with *NFPA 69* and a value of P_{max} determined for a nanometal similar in composition and size to the nanometal in the equipment.

22.14.4.5 Equipment and operations for application of nanometal coatings with flammable or combustible solvents shall be protected in accordance with applicable requirements in *NFPA 33* or *NFPA 34*.

22.14.5 Housekeeping.

22.14.5.1* A documented housekeeping program shall be established based on the hazards documented in the DHA for all nanometal particles and shall include special provisions for preventing personnel exposure to nanoparticles during cleaning.

22.14.5.1.1 The location and extent of potential nanoparticle deposits shall be described in the program documentation.

22.14.5.1.2 The likelihood of ignition during cleaning shall also be documented.

22.14.5.2 Personnel responsible for cleaning nanoparticle deposits shall be equipped with personal protective equipment (PPE) determined as part of the documented housekeeping program.

22.15 Additive Manufacturing

22.15.1 Retroactivity. The requirements of Section 22.15 shall apply retroactively.

22.15.2* General Requirements.

22.15.2.1* A DHA conducted per Chapter 7 and Section 22.7 shall include the 3D printers, condensate filter modules, powder conveying and collection systems, depowdering units, powder storage equipment, and all other additive manufacturing processes and equipment.

22.15.2.2* Qualifications. The DHA shall be performed by one or more qualified persons with combined knowledge of and experience in the pertinent AM technology and equipment, and assessing the fire, flash fire, explosion, and spontaneous ignition hazards associated with the combustible metal powders and condensate processed in the 3D printers and other additive manufacturing equipment.

22.15.2.3 Additive manufacturing facility construction and layout, including powder storage provisions, shall meet the requirements of Sections 22.16 through 22.18 for all applicable metals in addition to the requirements of Section 22.15.

22.15.2.4* Provisions for Emergency Shutdown for Systems Containing More than 50 lb (22.7 kg).

22.15.2.4.1 The control system shall automatically shut down on any of the following conditions:

- (1) Loss of purge gas
- (2) High chamber temperature 90°F (50°C) above normal operating temperature
- (3) Loss of vacuum

22.15.2.4.2* The additive manufacturing equipment shall be provided with a local and a remote manual emergency shutdown device.

22.15.2.4.2.1 For existing installations, the DHA shall determine whether a remote manual emergency shutdown device is required.

22.15.2.4.2.2 Where the automatic shutdown system required by 22.15.2.4.1 is installed as an explosion protection system in accordance with NFPA 69, the remote manual emergency shutdown device shall not be required.

22.15.2.4.2.3 Where multiple remote emergency shutdown switches are located in close proximity to one another, each remote shutdown switch shall be labeled as to which machine is controlled by the switch.

22.15.2.4.2.4 Shutdown shall deactivate the affected printing operations without creating additional hazards.

22.15.2.4.2.5 Shutdown shall not deactivate the purge gas or the vacuum system of the affected system.

22.15.2.5 Shipping and Handling Containers.

22.15.2.5.1* When nonmetallic containers or liners are used for powders with minimum ignition energies less than 100 mJ, the containers and liners shall be conductive or static dissipative.

22.15.3 Additive Manufacturing Equipment and Operations.

22.15.3.1 General.

22.15.3.1.1 All pieces of fixed equipment shall be grounded and bonded in accordance with NFPA 77.

22.15.3.1.2* Personnel involved in manually filling or emptying containers or vessels of powders with an MIE value less than

30 mJ, sieving, handling open containers of these powders, or cleaning these containers shall be grounded or bonded during such operations.

22.15.3.1.3* Control measures shall be employed to minimize the formation of suspended dust clouds during transfer of powder.

22.15.3.1.4* Where equipment operation requires manual removal of the part, the equipment in proximity to the part removal location shall be designed for installation in a Class II, Division 1, Group E location.

22.15.3.1.5 Portable vacuum cleaners used in additive manufacturing operations shall comply with the requirements in Section 25.4.

22.15.3.2* Storage of Powders.

22.15.3.2.1 The maximum allowable quantity of unused and recovered powder in the powder storage areas and AM production areas shall be documented by the DHA.

22.15.3.2.2 The determination of the allowable quantities of stored powder performed during the DHA shall address the following:

- (1)* The applicability of the maximum allowable storage quantities (MAQs) for combustible dusts, water-reactive materials, and flammable solids
- (2) The number and types of storage containers
- (3) The types and maximum storage quantities of cabinets, racks, or shelving units
- (4) The degree of hazard associated with handling the containers prior to and during storage

22.15.3.2.3 The DHA shall determine the requirements for how the container is stored in the AM production facility.

22.15.3.2.4 The storage of powders not in the production area shall be in accordance with the safety data sheet and general safe storage requirements of 9.6.6.4, 22.16.8, 22.17.8, and 22.18.8.

22.15.3.2.5 The DHA shall address the storage of recovered powders and waste powders.

22.15.3.2.6 The sealed powder containers shall be stored on floor areas or flat, level shelves inside storage cabinets or on storage racks that are protected from inadvertent contact by personnel and moving equipment.

22.15.3.2.7 The quantity of powder stored on shelves shall not exceed the maximum shelf load capacities recommended by the storage cabinet or rack manufacturer.

22.15.3.3 Powder Weighing Operations.

22.15.3.3.1* Powder weighing equipment shall be grounded.

22.15.3.3.2* Open conductive powder containers shall be bonded before weighing the container.

22.15.3.3.3 All containers or hoppers used for intermediate handling of powders shall be conductive or static dissipative.

22.15.3.3.4 Where the requirement of 22.15.3.3.3 is not met, a documented risk assessment, acceptable to the authority having jurisdiction, shall be completed to determine the need for alternative mitigations.

22.15.3.3.4.1 The risk assessment shall demonstrate that the use of the nonconductive containers or hoppers will not result in an ignition of the powder.

22.15.3.4 Sieving Operations.

22.15.3.4.1 Powder sieving equipment shall be bonded and grounded.

22.15.3.4.2* Conductive powder containers shall be bonded to the sieving equipment before the transfer of metallic powder to and from the sieving equipment.

22.15.3.4.3 Portions of sieving equipment that come in contact with powders shall be conductive or static dissipative.

22.15.3.4.4 Where the requirement of 22.15.3.4.3 is not met, a documented risk assessment, acceptable to the authority having jurisdiction, shall be completed to determine the need for alternative mitigations.

22.15.3.4.4.1 The risk assessment shall demonstrate that the use of the nonconductive containers or hoppers will not result in an ignition of the powder.

22.15.3.5* Powder Transfer Equipment.

22.15.3.5.1 Bonding and grounding connections shall be verified prior to the transfer of powder.

22.15.3.5.2 Containers used to transfer powder shall be designed to minimize spillage.

22.15.3.5.2.1 Powder containers shall be safely transported to avoid powder spills and dust cloud formation.

22.15.3.5.2.2 Transport containers shall be adequately closed and secured to the transport cart.

22.15.3.5.3 Operations transferring powder as dense phase powder transfer shall be ensured throughout the operation to be dense phase transfer operations and shall be in accordance with the powder transfer operations section of this chapter.

22.15.3.5.3.1 Powder transfer operations that cannot be ensured to be dense phase powder transfer shall be in accordance with the dust collection section of this chapter.

22.15.3.6 3D Printing.

22.15.3.6.1 Startup.

22.15.3.6.1.1* Before starting printing operations, the environment shall be established at an oxidant concentration below the limiting oxidant concentration (LOC) for the alloy and size distribution being processed per the requirements in Chapter 7, Deflagration Prevention by Oxidant Concentration Reduction, of NFPA 69.

22.15.3.6.1.2 The LOC shall be determined for the inert gas being used per the NFPA 69 requirements.

22.15.3.6.1.3 Inerting operations shall be in accordance with 22.9.4.3.2.2(B) through 22.9.4.3.2.2(H), and the inert gas supply shall be monitored per NFPA 69.

22.15.3.6.1.4* The setpoints for the oxygen sensors used to monitor the inerted equipment enclosures shall be documented by the DHA as determined in accordance with NFPA 69.

22.15.3.6.1.5* The calibration and replacement frequencies for the oxygen sensors that monitor the inerted equipment enclosures shall be documented by the DHA.

22.15.3.6.1.6* Before loading powder into the printer, the operator shall perform a visual inspection and follow the manufacturer's instructions to ensure that the printer and dust collector is free of residual materials from previous operations with other metal alloys, unless a DHA has determined that the materials are compatible under all conditions.

22.15.3.6.1.7 Purged enclosures shall be in accordance with NFPA 496.

22.15.3.6.2 Powder Bed Printing.

22.15.3.6.2.1 The environment shall be maintained at an oxidant concentration below the LOC for the alloy and size distribution being processed per the requirements for continuously monitored oxygen concentrations in Chapter 7, Deflagration Protection by Oxidant Concentration Reduction, of NFPA 69.

22.15.3.6.2.2 The LOC shall be determined for the inert gas being used per NFPA 69 requirements.

22.15.3.6.2.3 The inert gas supply shall be monitored per NFPA 69.

22.15.3.6.2.4 In addition to the requirements in NFPA 69, inerting operations shall be in accordance with 22.9.4.3.2.2(B) through 22.9.4.3.2.2(H).

22.15.3.6.2.5 Powder shall be transported from the bed to the build platform without forming dust clouds.

22.15.3.6.2.6* Loose powder and dust accumulations within the printer shall be controlled using inerted dust collection or an alternate method acceptable to the authority having jurisdiction.

22.15.3.6.3* Powder Spray Printing.

22.15.3.6.3.1 The environment shall be maintained around the powder spray at an oxidant concentration below the LOC for the alloy and size distribution being processed per the requirements for continuously monitored oxygen concentrations described in Chapter 7, Deflagration Protection by Oxidant Concentration Reduction, of NFPA 69.

22.15.3.6.3.2 The inert gas supply shall be designed to ensure an inert atmosphere envelope within the spray housing and on the build platform is maintained throughout the build process.

22.15.3.6.3.3 The inert gas supply shall be monitored per NFPA 69.

22.15.3.6.3.4 The powder spray equipment and operations shall be in accordance with the applicable provisions of NFPA 33.

22.15.3.6.3.5 Loose powder and dust accumulations within the printer shall be minimized using inerted dust collectors or using an alternate method acceptable to the authority having jurisdiction.

(A) In addition to the requirements in NFPA 69, inerting operations shall be in accordance with 22.9.4.3.2.2(B) through 22.9.4.3.2.2(H).

22.15.3.6.4* Other AM Processes. (Reserved)

22.15.3.6.5 Printed Part Extraction.

22.15.3.6.5.1* Printed part removal shall be performed to minimize the potential for formation of a dust cloud.

22.15.3.6.5.2* Compressed air or other compressed gas shall not be used for the removal of loose powder from printed objects during any part-extraction operation unless supported by the DHA.

22.15.3.6.5.3 Internal and external vacuum sources and hoses used for the removal of loose powder from printed parts shall be in accordance with 22.9.4.3.4 and 22.8.4.2.2.1.

22.15.3.6.5.4 Hoses for fixed or portable vacuum systems shall be conductive or static dissipative.

22.15.3.6.5.5 The printed part shall be transported from the printer in a container that prevents the dispersal of dust from the object into the surrounding area.

22.15.3.6.5.6* Means shall be provided within the printer to remove the majority of the residual trapped powder remaining on the part while the build chamber is still inerted.

22.15.3.6.5.7 Other means of printed part removal shall be permitted provided that a level of protection equivalent to the inerting of the build chamber is utilized.

22.15.3.6.5.8 The DHA shall address personnel hazards associated with venting of inert gas when opening the printer cabinet.

22.15.3.6.6* Post-Processing Operation.

22.15.3.6.6.1* Loose powder shall be removed from the printed object while it is in an inerted enclosure before post processing or using an alternate method acceptable to the authority having jurisdiction.

22.15.3.6.6.2 The remaining powder shall be removed while minimizing the potential for dust clouds and ignition sources (*see Section 22.15.4*).

22.15.3.6.6.3 If a vacuum method is used to remove the powder, the hose shall be conductive or static dissipative and securely bonded to the system.

22.15.3.6.6.4 Powder and dust generated during post processing shall be captured or conveyed in accordance with 22.9.4.3.

22.15.3.6.7 Fire Protection Systems.

22.15.3.6.7.1 Fire protection systems shall be in accordance with Section 22.10.

22.15.4 Equipment and Object Cleaning.

22.15.4.1* Equipment for cleaning shall be approved for use with the combustible powder being cleaned.

22.15.4.2 Equipment used for cleaning, including grounding and bonding, shall be in accordance with the requirements of 22.9.4.3.

22.15.4.3 Proper PPE, including the need for flash fire-resistant garments, shall be in accordance with 22.8.6.

22.15.4.4 Personnel cleaning process chambers, filter modules, transfer pipes and flexible hoses, and other interior and exterior equipment surfaces containing metal vapor condensate shall wear flame-resistant garments that comply with Section 8.6.

22.15.4.5* Cleaning operations shall avoid the formation of dust clouds.

22.15.4.6 Brushes used for cleaning operations shall be made of natural fiber.

22.15.4.7 Electrical classification shall be in accordance with 9.6.5.

22.15.5 Metal Vapor Condensate. The removal of powder bed filters shall comply with 22.15.5.1 through 22.15.5.4.

22.15.5.1 The following requirements are applicable to metal vapor condensate from combustible and noncombustible feed stock metals used in powder bed fusion AM applications.

22.15.5.2* Personnel changing and passivating the metal vapor condensate powder on the filter media surfaces and collected inside the powder containers shall wear flame-resistant garments that comply with Section 8.6.

22.15.5.3 Personnel changing and passivating the metal vapor condensate powder shall be grounded in accordance with 9.6.6.3.

22.15.5.4* The metal vapor condensate powder on the filter media surfaces and inside the powder containers shall be passivated using mineral oil or water.

22.15.5.5 The requirements in 22.15.5.4 shall not be required where the DHA determines that dry or air passivation methods are as effective as the wet methods in inhibiting the spontaneous flash fire hazard.

22.15.6* Training.

22.15.6.1* Operators shall be required to receive documented training classes addressing the safety and proper use of all additive manufacturing and cleaning equipment as described in equipment operation manuals.

22.15.6.1.1 Operators shall receive this training prior to operation of the equipment.

22.15.6.1.2 The training of operators shall be documented.

22.15.6.1.3 When 3D printers are used by multiple operators, a listing of approved operators shall be posted at the machine.

22.15.6.1.4 Where these classes are not available, the owner/operator shall develop an equivalent training program based on the current manufacturer's recommendations and knowledgeable and experienced users.

22.15.6.2* In addition to the requirements of Section 22.10, operators shall be trained in accordance with Section 9.8.

22.15.7 Emergency Response.

22.15.7.1 Emergency response shall be in accordance with Section 22.10, in addition to the equipment manufacturer's instructions.

22.15.7.2* Signs identifying the powder composition in the printer shall be posted in a location readily visible to emergency responders.

22.16 Alkali Metals.

22.16.1* General Provisions.

22.16.1.1 Retroactivity. The requirements of 22.16.1.2 through 22.16.1.4 shall apply to new and existing facilities.

22.16.1.2 Housekeeping.

22.16.1.2.1* Special Consideration. Alkali metals shall be kept away from sources of moisture.

22.16.1.3 Personal Protective Equipment (PPE). In addition to the requirements of this section, PPE shall be in accordance with 22.8.6.

22.16.1.3.1* PPE for Handling Solid Alkali Metals.

22.16.1.3.1.1 Personnel shall wear eye protection while handling solid alkali metals.

22.16.1.3.1.2 Personnel shall wear gloves while handling solid alkali metals.

22.16.1.3.1.3 Gloves shall have tight-fitting cuffs and shall be made of a material suitable for protection from caustic hazards.

22.16.1.3.1.4 Clothing worn by personnel handling solid alkali metals shall have no exposed pockets or cuffs that could trap and carry alkali metal residues.

22.16.1.3.2* PPE for Handling Molten Alkali Metals.

22.16.1.3.2.1 Personal protective equipment shall be worn and shall be compatible with the hazards of molten alkali metals.

22.16.1.3.2.2* An external clothing layer that is impervious to body moisture shall be worn for protection from splash.

22.16.1.4 Reactivity.

22.16.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g., iron oxide (rust)].

22.16.1.4.2 Eutectic Reactions. (Reserved)

22.16.1.5 Management of Change. Management of change shall be in accordance with Section 8.11.

22.16.1.6 Alternative Methodologies. (Reserved)

22.16.1.7 Test Results. (Reserved)

22.16.1.8 Other.

22.16.2 Facility Design Requirements.

22.16.2.1 Building Construction.

22.16.2.1.1* Floor drains shall not be permitted.

22.16.2.1.2 Where molten alkali metals are handled, dispensed, or stored, the handling area shall be provided with compatible and nonreactive containment.

22.16.2.1.2.1 The containment shall provide for a volume of 110 percent of the maximum amount of material that is contained or could be spilled in the area.

22.16.2.1.2.2 In areas where molten alkali metals are handled, wall-to-floor connections shall be sealed against the penetration of molten alkali metals.

22.16.2.1.3 Separation from Water.

22.16.2.1.3.1 Piping permitted by 22.9.3.7.3.3 shall be constructed of steel.

22.16.2.1.3.2 A sprinkler system(s) deemed appropriate in accordance with 22.9.9.5.2 shall be permitted.

22.16.2.1.3.3 Portions of buildings where alkali metals are stored, handled, processed, or used shall be separated by water-tight walls, ceilings, and door systems from adjacent areas where water can be present.

22.16.2.1.3.4 The floor shall be sloped in such a manner to prevent water from entering the alkali metals area.

22.16.2.1.4 NFPA Hazard Identification Markings.

22.16.2.1.4.1 Alkali metal handling, processing, and storage areas having quantities greater than 5 lb (2.3 kg) shall have diamond markings as specified in NFPA 704 to make emergency responders aware of the presence of water-reactive materials within the area.

22.16.2.1.4.2 The diamond markings shall be at least 18 in. (457.2 mm) on each side with appropriate size numbers and symbols as specified in NFPA 704.

22.16.2.2 Fire Protection.

22.16.2.2.1 Fire Protection. Fire protection shall be established in accordance with 22.9.9.

22.16.2.2.2* Because of the unique nature of alkali metal fires, a comprehensive fire protection plan shall be developed where alkali metal is processed, handled, used, or stored in accordance with 22.9.9 and Section 22.10.

22.16.2.3 Dust Collection. (Reserved)

22.16.2.4 Hazards Analysis. The hazards analysis shall be in accordance with Chapter 7 and Section 22.7.

22.16.3 Primary Metal Production.

22.16.3.1 Reduction. (Reserved)

22.16.3.2 Melting and Casting.

22.16.3.2.1* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

22.16.3.2.2 Molten alkali metals shall be contained in closed systems that prevent contact with air or reactive materials, except as required for the process.

22.16.3.2.3 Molten alkali metal piping systems shall be designed in conformance with ASME B31.3, *Process Piping*.

22.16.3.2.3.1 All pump seals and flange gaskets shall be made of compatible materials.

22.16.3.2.4 Molten alkali metal systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials, including moisture.

22.16.3.2.5 Molten alkali metals shall be handled in a detached building or in portions of a building separated from other exposures by fire-rated construction.

22.16.3.2.6 Where molten alkali metal is cast, molds, ladles, and other components that could come in contact with the molten alkali metal shall be free of incompatible materials, including moisture.

22.16.3.3 Refining. (Reserved)

22.16.4 Powder Production. (Reserved)

22.16.5 End Users of Powder. (Reserved)**22.16.6 Processing and Handling.****22.16.6.1 Machinery and Operations.**

22.16.6.1.1* Where alkali metals are processed with an ignitable (flammable or combustible) liquid, the requirements of NFPA 30 shall also be followed for the flammable or combustible liquids.

22.16.6.1.2 Moisture Protection.

22.16.6.1.2.1 Solid alkali metals shall be protected from moisture during handling.

22.16.6.1.2.2* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

22.16.6.1.2.3* Only the amount of alkali metal needed for an individual task or procedure shall be removed from containers.

22.16.6.1.2.4* Surplus alkali metal shall be placed in a container protected from moisture and sealed immediately.

22.16.6.1.3 Machining and Operations. (Reserved)**22.16.6.2 Flake and Paste. (Reserved)****22.16.6.3 Plasma Spray Operations. (Reserved)****22.16.6.4 Transfer Operations.****22.16.6.4.1 General Precautions.**

22.16.6.4.1.1 Alkali metals shall be handled only by trained personnel who are knowledgeable of the hazards associated with alkali metals.

22.16.6.4.1.2 The number of persons in alkali metal-handling areas during operations shall be limited to those necessary for the operation.

22.16.6.4.1.3 Access to alkali metal-handling areas by unauthorized personnel shall not be permitted.

22.16.6.4.1.4* Alkali metals shall not be handled in the presence of incompatible materials.

22.16.6.4.1.5 Dedicated storage of ordinary combustible materials or ignitable (flammable or combustible) liquids shall be prohibited in areas where alkali metals are handled, processed, or stored.

(A) Quantities of dry mineral oil necessary for safe storage and handling shall be permitted where lithium is processed, handled, or stored.

22.16.6.4.1.6* Allowable Quantity. The quantity of alkali metals permitted in processing areas shall be limited to that necessary for operations, but it shall not exceed the quantity required for 1 day or as needed for batch processing.

22.16.6.5 Processing Recycled Material. (Reserved)**22.16.7* Machining, Fabrication, Finishing, and Media Blasting.****22.16.7.1 Hot Work Operations.**

22.16.7.1.1 Hot work operations shall be in accordance with Section 8.5.

22.16.7.2 Chip Processing. (Reserved)**22.16.7.3 Dust Collection. (Reserved)****22.16.8 Storage and Handling.****22.16.8.1* Storage of Product.**

22.16.8.1.1 Alkali metals shall be handled, processed, and stored only in accordance with the requirements of Section 22.16.

22.16.8.1.2 Storage of Solid or Molten Alkali Metals.**22.16.8.1.2.1 General Precautions.**

(A)* Alkali metals shall be permitted to be stored in shipping containers that meet the requirements of UN *Recommendations on the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria* for the transportation of dangerous goods for alkali metals or in clean, moisture-free, compatible, and nonreactive metal-sealed containers dedicated for the storage of alkali metals.

(B) Alkali metals shall not be stored in containers previously used for the storage of incompatible materials.

(C)* Alkali metals shall not be stored in an area with incompatible materials.

(D) Alkali metals in nonbulk containers shall not be stored outside.

22.16.8.1.3 Solid Alkali Metals Storage.

22.16.8.1.3.1 Solid alkali metals shall be stored only on the ground floor.

22.16.8.1.3.2 There shall be no basement or depression below the alkali metals storage area into which water or molten metal could flow or fall during a fire.

22.16.8.1.3.3 The solid alkali metals storage area shall be isolated from water except for approved installation of automatic sprinkler systems for use in alkali metal storage.

22.16.8.1.3.4 Containers shall be stored individually or on pallets in an arrangement that allows visual inspection for container integrity.

(A) Containers on pallets shall be permitted to be stored in racks not more than 15 ft (4.5 m) high.

(B) Containers on pallets and not stored in racks shall be stacked in a stable manner not to exceed three pallets high.

(C) Aisle widths shall be established and approved by the authority having jurisdiction to provide for access to and for the removal of materials during emergency situations.

(D) Idle pallet storage shall not be permitted in alkali metal storage areas.

(E) Idle metal pallets shall be permitted in alkali metal storage areas.

22.16.8.1.4 Molten Alkali Metal Storage. Molten alkali metal storage shall be in closed systems and in separate buildings or portions of buildings designed solely for that purpose.

22.16.8.2 Scrap Handling, Storage and Disposal. Alkali metals shall be handled, processed, and stored in accordance with the requirements of Section 22.16.

22.16.8.2.1 NFPA Hazard Identification Markings.

22.16.8.2.1.1 Alkali metal handling, processing, and storage areas having quantities greater than 5 lb (2.3 kg) shall have diamond markings as specified in NFPA 704 to make emergency responders aware of the presence of water-reactive materials within the area.

22.16.8.2.1.2 The diamond markings shall be at least 18 in. (457.2 mm) on each side with appropriate size numbers and symbols as specified in NFPA 704.

22.16.8.3 Recycling.**22.16.8.4 Chip Processing. (Reserved)****22.16.9* Fire and Explosion Protection.**

22.16.9.1 Fire and explosion protection shall be in accordance with 22.9.9.

22.16.9.1.1* Alkali metal fire residues shall be stored in a designated and isolated location.

22.16.9.2 Housekeeping.**22.16.9.2.1 Dust Control. (Reserved)**

22.16.9.2.2* Special Consideration. Alkali metals shall be kept away from sources of moisture.

22.16.9.3 Control of Ignition Sources.

22.16.9.3.1 Control of ignition sources shall be in accordance with Section 9.6 and 22.9.6.

22.16.9.3.2 Alkali metal fire residue containers shall be permitted to be stored outside where placed in a steel overpack drum and inspected daily.

22.16.9.3.2.1* Alkali metal fire residues shall be disposed of within 7 days unless the AHJ allows longer storage.

22.16.9.3.2.2 Alkali metal fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

22.16.9.3.2.3 Alkali metal fire residues shall be disposed of in accordance with federal, state, and local regulations.

22.16.9.3.2.4 Prior to disposal, containers of alkali metal fire residue shall be inspected and the results recorded daily by individuals who are trained in the hazards of alkali metals and able to recognize potential problems associated with these containers.

22.16.9.3.2.5 Alkali metal fire residues shall be stored in metal containers that are recommended by the alkali metal manufacturer.

22.16.9.4* Hot Work Operations.

22.16.9.4.1 Hot work operations shall be in accordance with Section 8.5.

22.16.9.5 Control of Combustible Materials.

22.16.9.5.1 Areas in which ignitable (flammable and combustible) liquids are used shall be in accordance with the requirements of NFPA 30.

22.16.9.5.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 50 gal (189 L) or

greater shall use a less hazardous hydraulic fluid with a flash point greater than 200°F (93°C).

22.16.9.5.1.2 Dipping and coating applications of ignitable (flammable or combustible) liquids shall be done in accordance with NFPA 34.

22.16.9.5.1.3 Spray application of ignitable (flammable or combustible) liquids shall be done in accordance with NFPA 33.

22.16.9.5.2 Ordinary Combustible Storage.

22.16.9.5.2.1 Ordinary combustible materials such as paper, wood, cartons, and packing material shall not be stored or allowed to accumulate in processing areas unless necessary for the process and then only in designated areas.

22.16.9.5.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

22.16.9.5.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

22.16.9.5.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

22.16.9.5.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

22.16.9.6 Inspection, Maintenance, and Training. (Reserved)**22.16.10 Other. (Reserved)****22.17 Legacy Metals.****22.17.1* General.****22.17.1.1 Reactivity.**

22.17.1.1.1 It shall be the responsibility of the facility to evaluate processes and materials for potentially dangerous reactions that could occur in the course of their operations.

22.17.1.1.2 Reactive molten metals shall be contained in closed systems that prevent their unintentional contact with air or reactive materials.

22.17.1.2* Contact with Water. Water leakage inside or into any building where the water can contact water reactive metals shall be prevented to avoid possible spontaneous heating.

22.17.1.3* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g., iron oxide (rust)].

22.17.1.4* Eutectic Reactions. It shall be the responsibility of the facility to research processing and materials for potentially dangerous reactions and eutectic compositions that could occur in the course of their activities.

22.17.1.5 Dust Collection. Dust collection shall be in accordance with 9.4.3 and 22.9.4.3.

22.17.1.6 Ignition Sources. Electrical power and ignition sources shall be in accordance with Section 9.6 and 22.9.6.

22.17.1.7 Hot Work.

22.17.1.7.1 Hot work operations shall be in accordance with Section 8.5 and the requirements of this section.

22.17.1.7.2* All welding of legacy metals shall be carried out in an inert atmosphere, such as helium or argon, or under vacuum.

22.17.1.8 Fire Extinguishers. Portable fire extinguishers shall be in accordance with 22.9.9.3.

22.17.2 Facility Design Requirements. Facility design shall be in accordance with 22.9.3.6, 22.9.3.7, and the requirements of this section.

22.17.2.1 Dust Hazards Analysis (DHA).

22.17.2.1.1 Dust hazards analysis shall be in accordance with Chapter 7 and Section 22.7 and the requirements of this section.

22.17.2.1.2 A hazards analysis shall be performed to determine the material classification and the appropriate hazard classification (i.e., flammable solid, pyrophoric, or water reactive) based on the form or state of the material to determine the high hazard protection level of the structure based on the maximum allowable quantity (MAQ) per control area requirements.

22.17.2.2 Building Construction.

22.17.2.2.1 Buildings that contain metals in a combustible form shall be constructed in accordance with the locally adopted building code.

22.17.2.3 Protective Openings.

22.17.2.3.1 Means of egress shall be provided in compliance with NFPA 101.

22.17.3 Primary Metal Production (Smelting). This chapter shall not apply to the primary production of aluminum and magnesium.

22.17.3.1 Reduction. Fire and explosion hazards associated with metal production by chemical reduction methods, as well as the chemical reactivity hazards and the flammability properties of all reactants and reaction products, shall be assessed and documented.

22.17.3.1.1 Reactor vessels shall be air-cooled.

22.17.3.1.2 Sealed reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

22.17.3.1.3 All containers used to receive molten metal shall be cleaned and dried thoroughly before use.

22.17.3.1.4 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than that developed from the hazards analysis.

22.17.3.1.5 Combustible materials shall be minimized in the (sponge) collection area, well-ventilated, and free from other materials.

22.17.3.1.6 Dust resulting from the crushing of sponge shall be managed safely to minimize the risk of fires and explosions.

22.17.3.1.7 Storage areas shall be kept free of combustible materials, be well ventilated, be equipped with the required fire

protection equipment, and be plainly marked with "No Smoking" signs.

22.17.3.2 Refining. (Reserved)**22.17.3.3* Melting and Casting.**

22.17.3.3.1* All solid metal shall be thoroughly dried by preheating and shall be at a temperature not less than 121°C (250°F) throughout when coming into contact with molten metal.

22.17.3.3.2 Fuel supply lines to melting pots and preheating installations shall have remote fuel shutoffs and combustion safety controls in accordance with NFPA 86 or equivalent.

22.17.3.3.3* Prevention of Molten Metal Contact with Foreign Materials.

22.17.3.3.3.1 Areas of furnaces that can come into contact with molten metal in the event of a runout shall be kept dry and free of iron oxide.

22.17.3.3.3.2 Crucible interiors and covers shall be maintained free of iron oxide scale, which could fall into the molten metal.

22.17.3.3.3.3 Molten systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and be provided with the means to prevent contact with incompatible materials.

22.17.3.3.3.4 Melting pots and crucibles shall be inspected regularly.

22.17.3.3.3.5 Pots and crucibles that show evidence of possible failure or that allow molten metal to contact iron oxide, concrete, or other incompatible materials shall be repaired or discarded.

22.17.3.3.3.6 Iron scale and metal spillage shall be minimized in furnaces.

22.17.3.3.4 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

22.17.3.3.5 All molds shall be thoroughly preheated before pouring castings.

22.17.3.3.6 Extreme care shall be exercised when pouring molten metal castings to avoid spillage.

22.17.3.3.7 Personnel in areas where melting and casting occurs shall be evaluated for appropriate PPE per Section 8.6.

22.17.3.3.8* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

22.17.3.3.9 The fill used for furnace containment shall be designed to minimize the potential for the material to slough into the furnace cavity after an explosion.

22.17.3.3.10 Upper Chamber of the Furnace.

22.17.3.3.10.1* The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.

22.17.3.3.10.2 The release pressure of the rupture disc shall be at a gauge pressure of 20 psi (138 kPa) maximum.

22.17.3.3.10.3 Means shall be provided to prevent the influx of air through the pressure-relief port.

22.17.3.3.10.4* The furnace shall be equipped with a device that continuously senses pressure within the furnace.

(A) The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

(B) The furnace shall be equipped with the following:

- (1) Waterflow, temperature, and pressure sensors on cooling systems, which are necessary for safe furnace operations and to indicate contact with molten metal.
- (2) Furnace pressure sensors and recorders
- (3) Set point alarms on critical process systems to warn of abnormal conditions

(C) Furnaces shall comply with NFPA 86.

22.17.3.3.10.5 All furnace pits and bunkers shall be evaluated as confined spaces.

22.17.3.3.11* Molds and Crucibles.

22.17.3.3.11.1* Water-cooled crucibles shall be inspected to ensure that minimum wall thicknesses are maintained to prevent a breach of the crucible wall.

22.17.3.3.11.2 Because mold breaks are inevitable, the casting chamber shall be cooled or shall be large enough to serve as a heat sink, or both, to provide the protection necessary in the event of a spill.

22.17.3.3.11.3 Molds (and crucibles) for metal casting (melting) shall be made of material that is compatible with molten metal.

22.17.3.3.11.4 Molds (and crucibles) shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

22.17.3.3.11.5 All pieces of metal shall be clean and dry when charged to reactors.

22.17.3.3.12* Residue.

22.17.3.3.12.1 Residue from casting furnaces shall be passivated, placed in covered metal containers that allow for hydrogen gas venting, and moved to a designated storage or disposal area.

22.17.3.3.12.2 The containers specified in 22.17.3.3.12.1 shall be stored so that any hydrogen gas generated vents freely.

22.17.3.3.13 Water Supply.

22.17.3.3.13.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source on a drop in water pressure or waterflow.

22.17.3.3.13.2 An emergency source of cooling water shall be provided and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

22.17.3.3.13.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

22.17.3.3.14 Vacuum Arc Remelt (VAR) and Electroslag Remelting (ESR).

22.17.3.3.14.1* Water-cooled furnaces shall be located in a protective concrete vault, or the crucible and its water-jacket

shall be isolated to protect personnel and to minimize damage if an explosion occurs.

22.17.3.3.14.2* Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

22.17.3.3.14.3* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

22.17.3.3.14.4 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

22.17.3.3.14.5 Furnaces shall be equipped with the following equipment:

- (1) Arc voltage recorders and melting power recorders
- (2) Electrode position indicators
- (3) Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside furnace vaults

22.17.3.3.15 Electron Beam (EB) and Plasma Arc Melting (PAM). (Reserved)

22.17.3.3.16 Vacuum Induced Melting (VIM) and Skull. (Reserved)

22.17.4 Powder Production.

22.17.4.1 General.

22.17.4.1.1 Where powder is present, good housekeeping practices shall be maintained. (*See Section 8.4 and 22.8.4.*)

22.17.4.1.2 To minimize the risk of fire or explosion hazards in the handling of dry combustible metal powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of combustible metal powders.

22.17.4.1.3 Combustible metal powder shall be handled to avoid spillage and the creation of airborne dust.

22.17.4.1.4* Each container for powders shall be conductive and covered while in storage or in transit within the facility.

22.17.4.1.5 When powders are being charged to or discharged from machines, the containers shall be bonded to the equipment and grounded by a suitable grounding conductor.

22.17.4.1.6 Scoops, shovels, and scrapers used in the handling of powder shall be electrically conductive and shall be bonded and grounded.

22.17.4.1.7 Hand tools shall be made of spark-resistant materials.

22.17.4.1.8 When powder is being transferred between containers, the containers shall be bonded and grounded.

22.17.4.1.9 Equipment shall be constructed to mitigate the potential for ignition of metal powder.

22.17.4.1.10 Powder-handling or powder-processing areas shall not be used for the primary storage of metal powder.

22.17.4.1.11 Primary storage of ordinary combustible materials and ignitable (flammable and combustible) liquids shall be prohibited in metal powder-processing areas.

22.17.4.2 In-Plant Conveying of Powder.**22.17.4.2.1 Containers.**

22.17.4.2.1.1 In-plant transport or transfer of powders shall be done in covered conductive containers as described in 22.17.4.1.4.

22.17.4.2.1.2 Powered industrial trucks shall be selected in accordance with NFPA 505 and be consistent with 9.6.8.

22.17.4.2.1.3 All wheeled containers, hand trucks, and lift trucks shall be grounded.

22.17.4.3 Pneumatic Conveying. Pneumatic conveying shall be in accordance with 22.9.4.3.2.

22.17.4.4 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 22.9.4.3.2.1.

22.17.4.5 Dust Collectors. Dust collectors shall be in accordance with 9.4.3 and 22.9.4.3.

22.17.4.6 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 22.9.4.3.2.2.

22.17.4.7 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 22.9.6.15.

22.17.4.8 Powder Collection. Powder collection shall be in accordance with 22.9.4.3.5.

22.17.4.9 General Precautions.

22.17.4.9.1 In powder-handling or manufacturing buildings and in the operation of dust-conveying systems, every precaution shall be taken to avoid the production of sparks from static electricity, electrical faults, friction, or impact (e.g., iron or steel articles on stones, on each other, or on concrete).

22.17.4.9.2 Water leakage within or into any building where it can contact metal powder shall be prevented to avoid possible spontaneous heating and hydrogen generation.

22.17.4.9.3 Electrical heating of any resistance element or load to a high temperature in an area containing a dust hazard shall be prohibited.

22.17.4.9.4* Frictional heating shall be minimized using lubrication, inspection programs, and maintenance programs and by techniques recommended by the equipment manufacturer.

22.17.4.10 Requirements for Machinery.

22.17.4.10.1 All metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

22.17.4.10.2* All machinery shall be bonded and grounded to minimize the accumulation of static electric charge in accordance with NFPA 77 and Chapter 9.

22.17.4.10.2.1 The requirement of 22.17.4.10.2 shall apply to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled.

22.17.4.10.2.2* Static-dissipative belts shall be used on belt-driven equipment.

22.17.4.10.3* Only grounded and bonded bearings, properly sealed against dust, shall be used.

22.17.4.10.4 Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

22.17.4.10.5 High-strength permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into the manufacturing operations.

22.17.4.11 Startup Operations. All the machine-processing contact areas shall be thoroughly cleaned and free from water before being charged with metal and placed into operation.

22.17.4.12 Charging and Discharging. All powder containers not used for shipping into or out of the plant shall be made of metal.

22.17.4.13 Packaging and Storage.

22.17.4.13.1 Powder shall be stored in closed, noncombustible, non-lined steel drums or other closed conductive containers.

22.17.4.13.2 The containers shall be tightly sealed and stored in a dry location until ready for shipment or repacking.

22.17.4.13.3 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for ignition of the metal.

22.17.4.14* Only powder for immediate use shall be present in production areas.

22.17.4.14.1 Daily supplies of powder shall be allowed to be stored in the production area.

22.17.4.14.1.1 The powder shall be stored in covered containers and shall be segregated from other combustible materials.

22.17.4.14.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

22.17.4.14.1.3 The containers shall be protected from damage.

22.17.4.15 Transport of dry powders within manufacturing operations and storage of dry powders within manufacturing areas shall be done in covered conductive containers.

22.17.4.16 To minimize the risk of fire or explosion hazard in the handling of powders, the equipment and process shall be designed by persons experienced and knowledgeable in the hazards of niobium powders.

22.17.4.17 Drying of Powder. A hazards analysis acceptable to the authority having jurisdiction (AHJ) shall be conducted to determine appropriate methods and parameters for drying of powder based on the specific materials being handled and dried.

22.17.4.17.1* Water-wetted powder shall be dried at a temperature compatible with the specific metal and its surface area as determined by a hazards analysis.

22.17.4.17.2 Powders wetted with fluids other than water, when dried in air, shall be dried at a temperature governed by the characteristics of the fluid but not exceeding the temperature at which the powder readily oxidizes.

22.17.4.17.3* When drying powders under controlled atmospheric conditions (e.g., vacuum or inert atmosphere), if the temperature exceeds the oxidizing temperature, the powder shall be cooled to less than the oxidizing temperature prior to exposure to air.

22.17.4.17.4 Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.

22.17.4.17.5 A dry inert gas atmosphere shall be permitted to be recycled to the drying process if it passes through a filter, a dust collector, or an equivalent means of dust removal capable of removing 95 percent of the suspended particulate.

22.17.4.18 Powder Handling.

22.17.4.18.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

22.17.4.18.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

22.17.4.18.3 Hot zones of furnaces that handle metal powder in any form shall be provided with vacuum or inert atmospheres.

22.17.4.18.4 The furnaces shall be designed in accordance with NFPA 86.

22.17.4.18.5 To minimize the risk of fire or explosion hazards while handling dry metal powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of metal powder.

22.17.4.18.6 Only nonsparking tools and utensils shall be used in handling metal powder.

22.17.4.19* Dryers.

22.17.4.19.1 Dryers shall be constructed of noncombustible materials.

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

22.17.4.19.3 Outward-opening access doors or openings shall be provided in all parts of the dryer and connecting conveyors to allow inspection, cleaning, maintenance, and the effective use of extinguishing agents.

22.17.4.19.4* Products of combustion, as a result of a collector fire, shall be considered when designing wet collector installations.

22.17.4.19.5 Wet collectors posing a significant fire and evacuation risk shall have their exhaust air conveyed directly to the exterior of the building.

22.17.4.19.6 Explosion protection shall be provided as specified in 22.17.4.16.

22.17.4.19.7* Operating controls shall be designed, constructed, installed, and monitored so that required conditions of safety for operation of the heating system, the dryer, and the ventilation equipment are maintained.

22.17.4.19.8 Heated dryers shall have operating controls configured to maintain the temperature of the drying chamber within the prescribed limits.

22.17.4.19.9 Excess temperature-limit controls required in 22.17.4.19.7 shall initiate an automatic shutdown that performs at least the following functions:

- (1) Sounds an alarm at a constantly attended location to prompt emergency response
- (2) Shuts off the fuel or heat source to the dryer
- (3) Stops the flow of product into the dryer and stops or diverts the flow out of the dryer
- (4) Stops all airflow into the dryer
- (5)* Maintains purge flow of inert gas
- (6) Maintains coolant flow, if so equipped

22.17.4.19.10 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 22.17.4.19.9.

22.17.4.19.11 Heated dryers and their auxiliary equipment shall be fitted with separate excess temperature-limit controls arranged to supervise the following:

- (1) Heated air or inert gas supply to the drying chamber
- (2) Airstream or inert gas stream representative of the discharge of the drying chamber

22.17.4.19.12 All automatic shutdowns required by 22.17.4.19.10 shall require manual reset before the dryer can be returned to operation.

22.17.4.19.13 If the powder being dried has been determined, in its current form, to be combustible in accordance with Chapter 5, only dryers determined to be acceptable by the DHA shall be allowed to be used.

22.17.4.20 Powder Production.

22.17.4.20.1 Care shall be exercised to avoid the presence of an isolated conductor in the vicinity of powder being handled.

22.17.4.20.2* The use of humidifiers in facilities where dry powder is handled shall be considered.

22.17.4.20.3 Sintering furnaces that handle parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86.

22.17.4.20.4 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

22.17.4.20.5 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

22.17.4.21 Electrical Installations. (Reserved)

22.17.4.22 Explosion Prevention and Protection.

22.17.4.22.1* Explosion Risk Evaluation and Explosion Suppression Design. A documented risk evaluation acceptable to the AHJ shall be conducted in accordance with Chapter 7 and Section 22.7 to determine the level of explosion protection to be provided for the process. The risk evaluation shall take into account the specific nature and properties of the metal being handled.

22.17.4.22.2 Where explosion protection is required per 22.17.4.22.1, one or more of the following methods shall be used:

- (1) Equipment designed to contain the anticipated explosion pressure
- (2)* Correctly designed deflagration venting

- (3)* Explosion suppression system meeting the requirements of NFPA 69
- (4) Inert gas used to reduce the oxygen content within the equipment to below the level prescribed by NFPA 69
- (5)* Inert gas used to reduce the oxygen content within the equipment to below 50 percent of the limiting oxygen concentration (LOC) for the specific form of the material being processed
- (6) Oxidant concentration reduction in accordance with NFPA 69

22.17.4.22.3 If the method specified in 22.17.4.22.2(5) is used, test data for the specific dust and dilution combinations shall be provided and shall be acceptable to the AHJ.

22.17.4.22.4 Recirculating comfort air shall be permitted to be returned to the work area where tests conducted by an approved testing organization prove that the collector's efficiency is great enough to provide both personnel and property safety in the particular installation.

22.17.4.22.5 With regard to particulate matter in the cleaned air and accumulations of particulate matter and hydrogen in the work area, systems shall be periodically inspected and maintained to ensure correct operation.

22.17.4.23* Inerting. A supply of argon or helium as an inerting agent shall be provided on site at all times for blanketing and purging equipment.

22.17.4.24 Personnel Safety Precautions.

22.17.4.24.1 PPE shall be in accordance with Section 8.6 and the requirements of this section.

22.17.4.24.2* Personnel handling powder shall wear static-dissipative footwear and flame-resistant clothing that are designed to minimize the accumulation of powder. Static-dissipative footwear in conjunction with static dissipative flooring and flame-resistant clothing shall be used unless a hazards analysis shows that the footwear in conjunction with static-dissipative flooring and flame-resistant clothing is not required.

22.17.4.24.3 Personnel handling powder who wear gloves shall wear gloves made from conductive materials, unless other chemicals or hazardous materials in use require alternative materials of construction to provide protection.

22.17.4.24.4 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

22.17.4.24.5* Powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with powder.

22.17.4.24.6 Access to powder-handling areas by unauthorized personnel shall not be permitted.

22.17.5 End Users of Powder.

22.17.5.1 General. Processing, storage, and handling of combustible metal powders shall follow the requirements of Section 22.17 in addition to the fire and explosion prevention and mitigation requirements in Sections 22.8 through 22.16.

22.17.5.2 Powder Handling and Use. The provisions of 22.17.5 shall apply to operations including, but not limited to, the use of powder in the production of paste, flake powders, powdered metallurgy component manufacturing, fireworks

and pyrotechnics, propellants, plasma spray coating, chemical processing, and refractories.

22.17.5.3 Storage. Dry powder and paste shall be stored in accordance with the provisions of 22.17.8.1.

22.17.5.4* Handling. The requirements of 22.17.5 shall apply to both regular and "nondusting" grades of powder, as well as to paste.

22.17.5.5 Where powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with Section 8.4 and 22.8.4.

22.17.5.6* Scoops, shovels, and scrapers used in the handling of powder and paste shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials. (See 22.9.6.6.6.)

22.17.5.7* Equipment shall be constructed to mitigate the potential for ignition of powder.

22.17.5.8 A hazards analysis shall be performed for areas where powder is present to determine risk factors and applicable controls.

22.17.5.9 Where the hazards analysis shows that controls are required to manage the risk of static generation, and static dissipative flooring or static-dissipative floor mats are required, personnel shall wear static-dissipative footwear or equivalent grounding devices.

22.17.5.10* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of powder.

22.17.5.11 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

22.17.5.12* Powder Storage.

22.17.5.12.1 Powder-handling areas or powder-processing areas shall not be used for primary storage of powder.

22.17.5.12.1.1 Primary storage of ordinary combustible materials and ignitable (flammable and combustible) liquids shall be prohibited in powder-processing areas.

22.17.5.12.2 Daily supplies of powder shall be allowed to be stored in the production area.

22.17.5.12.2.1 The powder shall be stored in covered containers and shall be segregated from other combustible materials.

22.17.5.12.2.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

22.17.5.12.2.3 The containers shall be protected from damage.

22.17.5.12.3 Stacked Storage.

22.17.5.12.3.1 Where powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

22.17.5.12.3.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate firefighting operations.

22.17.5.12.4 Dry Powder Handling.

22.17.5.12.4.1* Precautions shall be taken to prevent spills or dispersions that produce dust clouds.

22.17.5.12.5 Wet Powder Handling. Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 176°F (80°C).

22.17.5.12.5.1 Powders wetted with fluids other than water, when dried in air, shall be dried at a temperature governed by the characteristics of the fluid but not exceeding 176°F (80°C).

22.17.5.12.5.2 When drying powders under controlled atmospheric conditions (for example, vacuum or inert atmosphere) and when the temperature exceeds 176°F (80°C), the powder shall be cooled to less than 176°F (80°C) prior to exposure to air.

22.17.5.12.6 Heat Treatment and Passivation.

22.17.5.12.6.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of powder.

22.17.5.12.6.2 Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54.

22.17.5.12.6.3 Furnaces shall comply with NFPA 86.

22.17.5.12.7 Personnel Safety Precautions.

22.17.5.12.7.1 Metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with powder.

22.17.5.12.7.2 Access to handling areas by unauthorized personnel shall not be permitted.

22.17.5.12.7.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

22.17.5.12.8 Powder Heat Treatment and Sintering.

22.17.5.12.8.1 After powder furnacing, the powder shall be passivated prior to exposure to air atmosphere.

22.17.5.12.8.2 Furnaced powder shall be cooled to 122°F (50°C) or less prior to starting passivation.

22.17.5.12.8.3 Furnaced powder shall be monitored during passivation to ensure that uncontrolled oxidation, resulting in an unacceptable temperature increase of the metal, does not occur.

22.17.5.12.9* Heat Treatment and Sintering of Compacts.

22.17.5.12.9.1* Sintered compacts shall be cooled to 122°F (50°C) or less prior to removal from the furnace.

22.17.5.12.9.2 Sintered compacts shall be isolated from other combustible materials until their temperature has stabilized below 122°F (50°C).

22.17.6 Processing and Handling.**22.17.6.1 Machining and Operations.**

22.17.6.1.1* Where metals are processed with an ignitable (flammable or combustible) liquid, the requirements of

NFPA 30 shall also be followed for the ignitable (flammable or combustible) liquids.

22.17.6.2 Requirements for Machinery.

22.17.6.2.1 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

22.17.6.2.2* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

22.17.6.2.3 Before being placed into operation, all areas of processing machinery that will be in contact with combustible metal shall be free of the following:

- (1) Foreign objects and materials
- (2) Water, where combustible metal is reactive with water

22.17.6.2.4* Wet Milling of Metal Powder. The requirements of 22.17.6.2.4.1 through 22.17.6.2.4.5 shall not apply to machining and rolling operations.

22.17.6.2.4.1* Where metal is added to a mill in the presence of a liquid that is chemically inert with respect to the metal, the milling shall be done in air in a vented mill or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

22.17.6.2.4.2* Where metal is slurried in tanks or processed in blenders or other similar equipment in the presence of a liquid that is chemically inert with respect to the metal, the operation shall be carried out in air or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

22.17.6.2.4.3 The dew point of the atmospheres in 22.17.6.2.4.1 and 22.17.6.2.4.2 shall be maintained below the point where condensation occurs.

22.17.6.2.4.4* Ventilation in accordance with NFPA 30 shall be maintained in areas where flammable or combustible solvents are handled, particularly in areas where combustible metal dusts or powders are present.

22.17.6.2.4.5 Solvent or slurry pumps shall be installed with controls that ensure that a flow exists and that the pumps run at safe operating temperatures.

22.17.6.3 Plasma Spray Operations.

22.17.6.3.1 For plasma spray operations, media collectors, if used, shall be located at a distance from the point of collection suitable to eliminate the possibility of hot metal particles igniting the filter media in the collector.

22.17.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

22.17.6.4 Transfer Operations.

22.17.6.4.1* Operations involving the transfer of combustible metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, and buildings from the fire or dust explosion hazards produced by airborne suspensions of combustible metal dusts or powders.

22.17.6.5 Processing Recycled Material. The requirements of Section 22.19 shall apply to processes handling recycled metal that is in a combustible form.

22.17.7* Machining, Fabrication, Finishing, and Media Blasting.

22.17.7.1 General Precautions.

22.17.7.1.1 Any equipment used for the machining, fabrication, or finishing of a single metal shall be dedicated to that metal only and marked with a placard that reads as follows:

WARNING

**(INSERT SPECIFIC METAL NAME) METAL ONLY —
FIRE OR EXPLOSION CAN RESULT WITH OTHER
METALS.**

22.17.7.1.2 Equipment producing metal in a combustible form shall be permitted to be used for other materials only if the system is thoroughly cleaned of all incompatible materials prior to and after its use.

22.17.7.1.3 It shall be permitted to use equipment for the machining, fabrication, or finishing of multiple metals without placarding where the risk of a thermite reaction (*see 22.17.1.3*) has been shown to be inapplicable to those metals through the performance of a hazards analysis.

22.17.7.2* Machining and Sawing Operations.

22.17.7.2.1* Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of metals.

22.17.7.2.1.1 The collected solids shall be moved to a designated storage or disposal area.

22.17.7.2.1.2 Crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily to a designated storage or disposal area.

22.17.7.2.1.3 Where fully dense forms of legacy metals are conditioned via grinding or sanding operations, consideration shall be given to ensure that the residual dusts produced are handled in a safe fashion.

22.17.7.2.1.4 A hazards analysis shall be conducted to ensure that these operations do not contribute to fugitive dust accumulation.

22.17.7.2.1.5 If dust collection is used for grinding and sanding applications, take-up hoods shall be designed to minimize the accumulation of dust.

22.17.7.2.2 Cutting Tools.

22.17.7.2.2.1* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal.

22.17.7.2.2.2 Cutting tools shall not be permitted to ride on the metal without cutting, because frictional heat can ignite any fine metal that is scraped off.

22.17.7.2.2.3 Because frictional heat can ignite any fine metal that is scraped off, the cutting tool shall be backed off as soon as the cut is finished.

22.17.7.2.2.4 Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

22.17.7.2.3 All machines shall be provided with a pan or tray to catch chips or turnings.

22.17.7.2.3.1 The pan construction shall be sufficient to minimize the potential for burn-through.

22.17.7.2.3.2 In the case of fire in the chips, turnings, or compacted metal powder, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of the metal, until the fire has been extinguished and the material has cooled to ambient temperature.

22.17.7.2.3.3* The pan or tray shall be installed so that it is accessible for chip, turning, or compacted metal powder removal and for application of an extinguishing agent to control a fire.

22.17.7.2.4 Consideration shall be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

22.17.7.2.4.1 During metal-machining operations, chips shall be removed from the point of generation by continuous or batch removal.

22.17.7.2.4.2 Periodic removal of metal chips from buildings and machinery shall be carried out as frequently as conditions warrant.

22.17.7.2.4.3* All metal chips, oily crushed lathe turnings, raw turnings, and swarf shall be collected in covered metal containers dedicated to that specific metal only and removed daily, at a minimum, to a safe storage or disposal area.

22.17.7.2.4.4 It shall be permitted to collect multiple metals in the same container where the risk of a thermite reaction (*see 22.17.1.3*) has been shown to be inapplicable for those metals through the performance of a hazards analysis.

22.17.7.2.4.5 Floor sweepings and other waste materials shall be placed in metal containers other than those used for the primary collection of metals, metal scrap, and metal waste.

22.17.7.2.5 Coolant.

22.17.7.2.5.1 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

22.17.7.2.5.2* Ignitable (flammable or combustible) liquids shall be handled in accordance with NFPA 30.

22.17.7.2.5.3* Coolants with a flash point greater than 200°F (93°C) shall be permitted for wet grinding, cutting, or sawing operations where a hazards analysis has shown it to be acceptable.

22.17.7.2.5.4 The coolant shall be filtered on a continuous basis, and the collected solids shall not be allowed to accumulate in quantities greater than 5 gal (19 L) and shall be removed to a safe storage or disposal area.

22.17.7.2.5.5* Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems shall use a fluid with a flash point greater than 200°F (93°C).

22.17.7.3* Machining Magnesium.

22.17.7.3.1 The specific requirements of 22.17.7.3 shall apply only to operations using magnesium.

22.17.7.3.2 Periodic removal of magnesium chips from buildings and machinery shall be carried out as frequently as conditions warrant.

22.17.7.3.3 Chips shall be removed to a safe storage or disposal area.

22.17.7.3.3.1 Floor sweepings and other waste materials shall be placed in metal containers other than those used for the primary collection of metal, metal scrap, and metal waste.

22.17.7.3.4 Areas in which ignitable (flammable and combustible) liquids are used shall be in accordance with the requirements of NFPA 30.

22.17.7.3.5 Dust Collection. Dust collection shall be in accordance with 9.4.3 and 22.9.4.3.

22.17.7.3.6* Machining.

22.17.7.3.6.1 Cutting tools shall not be permitted to ride on the metal without cutting, because frictional heat can ignite any fine metal that is scraped off.

(A) Because frictional heat can ignite any fine metal that is scraped off, the cutting tool shall be backed off as soon as the cut is finished.

(B) Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

22.17.7.3.6.2* When drilling deep holes (depth greater than five times the drill diameter) in magnesium, high-helix drills (45 degrees) shall be used to prevent packing of the chips produced.

22.17.7.3.6.3 Relief shall be maintained on tools used in grooving and parting operations, because the tool tends to rub the sides of the groove as it cuts.

(A) Side relief shall be 5 degrees.

(B) End relief shall be from 10 degrees to 20 degrees.

22.17.7.3.6.4 If lubrication is needed, as in tapping or extremely fine grooving, a high-flash point lubricant shall be used.

(A) Water, water-soluble oils, and oils containing more than 0.2 percent fatty acids shall not be used, because they can generate flammable hydrogen gas.

(B) Special formulated coolant fluids (water-oil emulsions) that specifically inhibit the formation of hydrogen gas shall be permitted.

22.17.7.3.6.5 Where compressed air is used as a coolant, special precautions shall be taken to keep the air dry.

22.17.7.3.6.6 All machines shall be provided with a pan or tray to catch chips or turnings.

(A) The pan or tray shall be installed such that it can be readily withdrawn from the machine in case of fire.

(B) The pan shall be readily accessible for chip removal and for application of an extinguishing agent to control a fire.

(C) During magnesium-machining operations, chips shall be removed from the point of generation by continuous or batch removal.

(D) Accumulation of chips at the point of generation shall not exceed 3 lb (1.4 kg) dry weight.

(E) All chips shall be stored in covered noncombustible containers and removed to a storage area in accordance with 22.17.8.3.

(F) In case of a fire in the chips, the pan or tray shall be immediately withdrawn from the machine but shall not be picked up or carried away until the fire has been extinguished.

22.17.7.3.7 Cleaning.

22.17.7.3.7.1 Systematic cleaning of the entire grinding area, including roof members, pipes, conduits, and so on, shall be carried out daily or as often as conditions warrant.

22.17.7.3.7.2 Cleaning shall be done using soft brushes and conductive, nonsparking scoops and containers.

22.17.7.3.7.3* Vacuum cleaners shall not be used unless they are specifically listed for use with magnesium powder or dusts.

22.17.7.3.7.4 Machinery and equipment using grinding wheels shall not be used for processing other metals until the entire grinder and the dust collection system are thoroughly cleaned, and the grinding wheel or belt shall be replaced prior to work on other metals.

22.17.7.3.8 Drawing, Spinning, and Stamping.

22.17.7.3.8.1 Reliable means to prevent overheating shall be provided where magnesium is heated for drawing or spinning.

22.17.7.3.8.2 Clippings and trimmings shall be collected at frequent intervals and placed in clean, dry steel or other noncombustible containers.

22.17.7.3.8.3 Fine particles shall be handled according to the requirements of Section 8.4, 22.8.4, 9.4.3, and 22.9.4.3.

22.17.7.3.9* Heat Treating.

22.17.7.3.9.1 A standard procedure for checking the uniformity of temperatures at various points within heat-treating furnaces shall be established.

22.17.7.3.9.2 Furnaces shall be checked prior to use and at regular intervals during use to identify undesirable hot spots.

22.17.7.3.9.3* Gas- or oil-fired furnaces shall be provided with combustion safety controls.

22.17.7.3.9.4 All furnaces shall have two sets of temperature controls operating independently.

(A) One set of temperature controls shall maintain the desired operating temperature.

(B)* The other set of temperature controls, operating as a high-temperature limit control, shall cut off fuel or power to the heat-treating furnace at a temperature above the desired operating temperature.

22.17.7.3.9.5 Magnesium parts to be put in a heat-treating furnace shall be free of magnesium turnings, chips, and swarf.

22.17.7.3.9.6 Combustible spacers on pallets shall not be used in a heat-treating furnace.

22.17.7.3.9.7* Aluminum parts, sheets, or separators shall not be included in a furnace load of magnesium.

22.17.7.3.9.8 There shall be strict adherence to the heat-treating temperature cycle recommended by the alloy manufacturer.

22.17.7.3.9.9* Molten salt baths containing nitrates or nitrites shall not be used for heat-treating magnesium alloys.

22.17.7.3.9.10* Magnesium and aluminum metals shall be segregated and easily identifiable to avoid the possibility of accidental immersion of magnesium alloys in salt baths used for aluminum.

22.17.7.3.9.11* Furnaces used to heat magnesium or magnesium alloys shall be inspected and cleaned as necessary to remove any accumulation of loose iron oxide scale.

22.17.8 Storage and Handling.

22.17.8.1 Storage of Powder.

22.17.8.1.1* Storage of materials in closed, noncombustible containers shall be permitted except as noted for sponge. (See 22.17.8.1.11.2.)

22.17.8.1.1.1 Powder shall be stored in covered containers.

22.17.8.1.2 Containers from which a portion of powder has been removed shall be carefully covered and resealed.

22.17.8.1.3 Storage areas shall be free of combustible goods (other than the container used to store the powder), well ventilated, equipped with the required fire protection equipment, and plainly marked with "No Open Flame" signs.

22.17.8.1.4 Containers shall be kept free of contact with water or moisture.

22.17.8.1.5 Powder packed in sealed containers shall be permitted to be stored in commercial or public warehouses if they are of fire-resistive, noncombustible, or limited combustible construction as defined in NFPA 220 or are of other construction types protected with an automatic sprinkler system.

22.17.8.1.6 Storage with Incompatible Materials.

22.17.8.1.6.1* Powder shall be segregated from incompatible materials and combustible materials.

22.17.8.1.7 Where powder is collected or stored in containers, material handling equipment with sufficient capability to remove any container from the immediate area in the case of an emergency shall be readily available.

22.17.8.1.8* Where powder is stored in sealed containers, the height at which it is stored shall be determined based on the mass of the metal involved to prevent container and pallet deformities due to stacking.

22.17.8.1.8.1 Stacked storage shall be arranged to ensure stability.

22.17.8.1.8.2 Aisles shall be provided for maneuverability of material-handling equipment, for ready accessibility, and to facilitate incipient firefighting operations.

22.17.8.1.8.3* Where drums or other containers are used for storage, storage shall be limited to a height that would require no more than three movements using available equipment to move a stack.

22.17.8.1.8.4 Stack height shall not exceed 10 ft (3.1 m).

22.17.8.1.9 The available equipment shall be capable of moving the maximum weight of material (per pallet or container).

22.17.8.1.10 Leakage or condensation from roofs, floors, walls, drains, steam, water lines, or radiators shall be avoided.

22.17.8.1.11 Sponge Storage.

22.17.8.1.11.1 Sponge shall be stored in closed metal containers.

22.17.8.1.11.2 Containers shall not be sealed unless they are inerted.

22.17.8.1.11.3 Storage of sponge shall comply with 22.17.8.1.

22.17.8.2 Scrap Handling, Storage, and Disposal. Scrap handling, storage, and disposal shall be in accordance with Section 22.19.

22.17.8.2.1 Open storage of sheets, plates, forgings, or massive pieces of scrap shall be permitted as they present no fire risk.

22.17.8.2.2 Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

22.17.8.2.3 Covered, vented steel containers shall be used to transport collected sludge (from wet dust collectors) to a safe storage area or for disposal.

22.17.8.2.4 Sludge shall be disposed of in accordance with local, state, and federal regulations.

22.17.8.2.5 Storage of scrap, chips, fines, and dust that are ignitable shall be isolated and segregated from other combustible materials to prevent propagation of a fire.

22.17.8.3 Other Production Materials.

22.17.8.3.1 Magnesium Operations. All magnesium storage, handling, and processing operations in niobium, tantalum, titanium, zirconium, and hafnium production operations shall be in accordance with the requirements of 22.17.8.6.

22.17.8.3.2 Sodium Operations. All sodium storage, handling, and processing operations shall be in accordance with Section 22.16.

22.17.8.3.3 Ignitable (Flammable and Combustible) Liquids. Storage and handling of ignitable (flammable and combustible) liquids shall be in accordance with NFPA 30.

22.17.8.3.4 Chlorine shall be handled and stored in accordance with accepted industry practice.

22.17.8.3.5 Bulk containers of liquid metal x tetrachloride (XCl_4) shall be stored in a well-ventilated place located away from areas of acute fire hazard.

22.17.8.3.6 Containers shall be identified plainly and sealed tightly until used.

22.17.8.4 Recycling. Where a recycling facility handles metals in a combustible form, the requirements of Section 22.19 shall apply.

22.17.8.5 Chip Processing. (Reserved)

22.17.8.6 Storage and Handling of Magnesium. The specific requirements of 22.17.8.6 shall apply only to storage and handling of magnesium.

22.17.8.6.1* Storage of Pigs, Ingots, and Billets.

22.17.8.6.1.1 The size of piles of magnesium pigs, ingots, and billets shall be limited.

(A) Minimum aisle widths shall be based on the height of the pile per 22.17.8.6.1.2(H).

(B) The pile height shall not exceed 20 ft (7.1 m).

22.17.8.6.1.2 Yard (Outdoor) Storage.

(A) Magnesium ingots shall be carefully piled on firm and generally level areas to prevent tilting or toppling.

(B) Storage areas and yard pavement shall be well drained.

(C) The storage area shall be kept free of grass, weeds, and accumulations of combustible materials.

(D) Combustible flooring or supports shall not be used under piles of ingots.

(E) The quantity of magnesium stored in any pile shall be kept to a minimum.

(F) In no case, other than under the conditions of 22.17.8.6.1.2(G), shall the amount of magnesium stored exceed 100,000 lb (45,400 kg).

(G) The quantities of magnesium stored shall be permitted to be increased up to a maximum of 1,000,000 lb (454,000 kg) per pile when the following requirements are met:

- (1) Provision has been made for drainage of water away from stored material.
- (2) The aisle widths are equal to the pile height plus 10 ft (3.1 m) but no less than 15 ft (4.5 m).
- (3) The piles are not more than 10 ft (3.1 m) wide.

(H) Aisle width shall be at least one-half the height of the piles and shall be at least 10 ft (3.1 m).

(I) Readily combustible material shall not be stored within a distance of 25 ft (7.7 m) from any pile of magnesium ingots.

(J) An open space equal to the height of the piles plus 10 ft (3.1 m) shall be provided between the stored magnesium ingots and adjoining property lines where combustible material or buildings are exposed or where the adjacent occupancy can provide fire exposure to the magnesium.

22.17.8.6.1.3* Indoor Storage.

(A) Indoor storage shall be in buildings of noncombustible construction.

(B) Floors shall be well drained to prevent accumulation of water in puddles.

(C) Supports and pallets used under piles of magnesium ingots shall be noncombustible.

(D) The quantity of magnesium ingots stored in any one pile shall be kept to a minimum.

(E) In no case, other than under the conditions of 22.17.8.6.1.3(F), shall the amount of magnesium stored exceed 50,000 lb (23,000 kg).

(F) The quantities of magnesium stored shall be permitted to be increased up to a maximum of 500,000 lb (227,800 kg) per pile when the following requirements are met:

- (1) The piles are not more than 10 ft (3.1 m) wide.
- (2) If combustible materials are stored without the benefit of separation by fire wall or fire barrier wall from the magnesium storage, the building is sprinklered.

(G) Aisle widths shall comply with 22.17.8.6.1.2(H).

(H) Combustible material shall not be stored within a distance of 25 ft (7.7 m) from any pile of magnesium pigs, ingots, and billets.

22.17.8.6.2 Storage of Heavy Castings.

22.17.8.6.2.1 Except under the conditions of 22.17.8.6.2.2, buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

22.17.8.6.2.2 Storage shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system.

22.17.8.6.2.3* Floors shall be of noncombustible construction and shall be well drained to prevent accumulation of water in puddles.

22.17.8.6.2.4 All magnesium castings shall be clean and free of chips or fine particles of magnesium when being stored.

22.17.8.6.2.5 Storage Piles.

(A) The size of storage piles of heavy magnesium castings, either in cartons or crates or free of any packing material, shall be limited to 1270 ft³ (36 m³).

(B) Aisles shall be maintained to allow for inspection and effective use of fire protection equipment.

22.17.8.6.2.6 Aisle width shall be at least one-half the height of the piles and at least 10 ft (3.1 m).

22.17.8.6.2.7* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or other packing materials are present.

22.17.8.6.3 Storage of Light Castings.

22.17.8.6.3.1 Building Construction.

(A) Except under the conditions of 22.17.8.6.3.1(B), light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage by 25 ft (7.7 m).

(B) Storage of light castings shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system. (See 22.17.8.6.3.5.)

22.17.8.6.3.2 Piles of stored light magnesium castings, either in cartons or crates or without packing, shall be limited in size to 1000 ft³ (28 m³).

22.17.8.6.3.3 Light castings shall be segregated from other combustible materials and shall be kept away from flames or sources of heat capable of causing ignition.

22.17.8.6.3.4 Aisle widths shall be at least one-half the height of the piles and at least 10 ft (3.1 m).

22.17.8.6.3.5* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

22.17.8.6.4 Storage in Racks or Bins.

22.17.8.6.4.1 Racks shall be permitted to be extended along walls in optional lengths.

22.17.8.6.4.2 Aisle spaces in front of racks shall be equal to the height of the racks.

22.17.8.6.4.3 All aisle spaces shall be kept clear.

22.17.8.6.4.4 Combustible rubbish, spare crates, and separators shall not be allowed to accumulate within the rack space.

22.17.8.6.4.5 Separators and metal sheets shall not be stacked on edges and leaned against racks, because they will prevent heat from a small fire from activating automatic sprinklers and will act as shields against sprinkler discharge.

22.17.8.6.5 Storage of Scrap Magnesium.

22.17.8.6.5.1 Subsection 22.17.8.6.5 shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

22.17.8.6.5.2 Buildings used for the indoor storage of magnesium scrap shall be of noncombustible construction.

22.17.8.6.5.3 Dry magnesium scraps shall be kept well separated from other combustible materials.

(A) Scraps shall be kept in covered steel or other noncombustible containers and shall be kept in such a manner or location that they will not become wet.

(B) Outside storage of magnesium fines shall be permitted if such storage is separated from buildings or personnel and great care is exercised to prevent the fines from becoming wet.

22.17.8.6.5.4* Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

(A) Sources of ignition shall be kept away from the top of the container and the vent.

(B) Containers shall not be stacked.

22.17.8.6.5.5 Storage of dry scrap in quantities greater than 50 ft³ (1.4 m³) [six 55 gal drums (six 208 L drums)] shall be kept separate from other occupancies by fire-resistive construction without window openings or by an open space of at least 50 ft (15 m), and such buildings shall be well ventilated to avoid the accumulation of hydrogen in the event that the scrap becomes wet.

22.17.8.6.5.6 Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers, pending salvage.

22.17.8.6.5.7 Oily rags, packing materials, and similar combustibles shall not be permitted in storage bins or areas that store solid magnesium scrap.

22.17.8.6.5.8 The use of automatic sprinklers in magnesium scrap storage buildings or areas shall be prohibited.

22.17.8.6.6 Storage of Magnesium Powder.

22.17.8.6.6.1 Buildings used to store magnesium powder shall be of noncombustible, single-story construction.

22.17.8.6.6.2 The use of automatic sprinklers in magnesium powder storage buildings shall be strictly prohibited.

22.17.8.6.6.3 Magnesium powder shall be kept well separated from other combustible or reactive metals.

22.17.8.6.6.4 Magnesium powder shall be stored in closed steel drums or other closed noncombustible containers, and the containers shall be stored in dry locations.

22.17.8.6.6.5 Magnesium powder storage areas shall be kept dry and shall be checked for water leakage.

22.17.8.6.6.6* Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 18 ft (5.5 m).

(A) Storage shall be stacked in a manner that ensures stability.

(B) Containers shall not be allowed to topple over.

22.17.8.6.7 Storage of Other Magnesium Products.

22.17.8.6.7.1* Subsection 22.17.8.6.7 shall apply to the storage of parts and components in warehouses, wholesale facilities, factories, and retail establishments in which magnesium makes up 50 percent or more of the article's composition on a volumetric basis or where the magnesium-containing assemblies as packaged or stored exhibit the burning characteristics of magnesium.

22.17.8.6.7.2 Storage in quantities greater than 50 ft³ (1.4 m³) shall be separated from storage of other materials that are either combustible or are contained in combustible containers by aisles with a minimum width equal to the height of the piles of magnesium products.

22.17.8.6.7.3 Magnesium products stored in quantities greater than 1000 ft³ (28 m³) shall be separated into piles, each not larger than 1000 ft³ (28 m³), with the minimum aisle width equal to the height of the piles but in no case less than 10 ft (3.1 m).

22.17.8.6.7.4* The storage area shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 1000 ft³ (28 m³) is contained in a building of combustible construction
- (2) Where magnesium products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 30 ft (9 m) of the magnesium

22.17.9 Fire and Explosion Prevention.

22.17.9.1 Fire and explosion protection shall be in accordance with 22.9.9 and Section 22.10.

22.17.9.2 Scope. Section 22.17.9 shall apply to new and existing facilities where combustible dusts, pastes, and powders are present.

22.17.9.3 Control of Ignition Sources. Control of ignition sources shall be in accordance with Section 9.6 and 22.9.6.

22.17.9.4 Hot Work Operations. Hot work operations in facilities covered by this chapter shall be in accordance with Section 8.5.

22.17.9.5 Control of Combustible Materials.

22.17.9.5.1 Areas in which ignitable (flammable and combustible) liquids are used shall be in accordance with the requirements of NFPA 30.

22.17.9.5.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 50 gal (189 L) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 200°F (93°C).

22.17.9.5.1.2 Dipping and coating applications of ignitable (flammable or combustible) liquids shall be done in accordance with NFPA 34.

22.17.9.5.1.3 Spray application of ignitable (flammable or combustible) liquids shall be done in accordance with NFPA 33.

22.17.9.5.2 Ordinary Combustible Storage.

22.17.9.5.2.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in processing areas unless necessary for the process, and then only in designated areas.

22.17.9.5.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal.

22.17.9.5.2.3 Where ordinary combustible materials are necessary for the process and are stored in designated areas, 22.17.9.5.2.1 shall not apply.

22.17.9.5.2.4* Floor sweepings from operations shall be permitted to contain small amounts of ordinary combustible materials and shall be stored in separate containers.

22.17.9.5.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

22.17.9.5.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

22.17.9.5.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

22.17.9.5.4 Safety Inspection.

22.17.9.5.4.1 A thorough inspection of the operating area shall take place on an as-needed basis to help ensure that the equipment is in good condition and that proper work practices are being followed.

22.17.9.5.4.2 Periodic inspections shall be conducted, as frequently as conditions warrant, to detect the accumulation of excessive chips or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

22.17.9.5.4.3 The inspection shall be conducted by a person(s) knowledgeable in the proper practices who shall record the findings and recommendations.

22.17.9.5.4.4 Records of the inspections specified in 22.17.9.5.4.1 and 22.17.9.5.4.3 shall be kept.

22.17.9.5.5* Employee Training Program. Training programs shall be instituted to inform employees about the hazards involved in the manufacture of powder, paste, or granules and the hazards involved in processing or finishing operations that generate fine combustible dust, as appropriate to the operation.

22.18 Other Metals.

22.18.1 General Provisions.

22.18.1.1 Retroactivity. The requirements of 22.18.1.2 through 22.18.1.5 shall apply to new and existing facilities.

22.18.1.2 Housekeeping. Housekeeping shall be in accordance with Section 8.4 and 22.8.4.

22.18.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 8.6.

22.18.1.4 Reactivity. It shall be the responsibility of the facility to evaluate processes and materials for potentially dangerous reactions that could occur in the course of their operations.

22.18.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of reduced fines or molten material with metal oxides that exothermically react with the reduced metal.

22.18.1.4.2 Eutectic Reactions. (Reserved)

22.18.1.4.3 Contact with Water. (Reserved)

22.18.1.5 Management of Change. Management of change shall be in accordance with Section 8.11.

22.18.1.6 Alternative Methodologies. (Reserved)

22.18.1.7 Test Results. (Reserved)

22.18.1.8 Other. (Reserved)

22.18.2 Facility Design Requirements.

22.18.2.1 Dust Collection. Dust collection shall be in accordance with 9.4.3 and 22.9.4.3.

22.18.2.2 Hazards Analysis.

22.18.2.2.1 Hazards analysis shall be in accordance with Chapter 7 and Section 22.7.

22.18.2.2.2 A hazards analysis shall be performed to determine the material classification and the appropriate hazard classification (i.e., flammable solid, pyrophoric, or water reactive) based on the form or state of the material to determine the high hazard protection level of the structure based on the maximum allowable quantity (MAQ) per control area requirements.

22.18.3 Primary Metal Production.

22.18.3.1 Reduction. (Reserved)

22.18.3.2 Melting and Casting.

22.18.3.2.1* Water-cooled vacuum arc furnaces shall be designed with safety interlock systems that will allow the furnace to operate only if there is sufficient cooling waterflow to prevent over-temperature of the melting crucible.

22.18.3.2.2 Vacuum arc furnace electrodes shall be firmly affixed to the electrode stinger in such a fashion that the electrode will not become detached during the melting operation.

22.18.3.2.3 Buildings used for the melting and casting of metals shall be noncombustible.

22.18.3.2.4 Floors shall be kept free of standing water.

22.18.3.2.5* All solid metal shall be thoroughly dried throughout by preheating or other methods prior to coming into contact with molten metal.

22.18.3.2.6 Ovens and furnaces shall comply with NFPA 86.

22.18.3.2.7 Fuel supply lines shall comply with NFPA 54.

22.18.3.2.8 Use of ignitable (flammable and combustible) liquids shall comply with NFPA 30.

22.18.3.2.9 Areas of furnaces that can come into contact with molten metal in the event of a runout shall be kept dry and free of metal oxides that exothermically react with the molten metal.

22.18.3.2.10 Crucible interiors and covers shall be maintained free of metal oxides scale that exothermically react with the molten metal.

22.18.3.2.11 Molten metal systems shall overflow or relieve to secondary containments designed to handle 110 percent of the largest expected failure and shall be provided with the means to prevent contact with incompatible materials.

22.18.3.2.12 Pots and Crucibles.

22.18.3.2.12.1 Melting pots and crucibles shall be inspected regularly.

22.18.3.2.12.2 Pots and crucibles that show evidence of possible failure or that allow molten metal to contact metal oxides that exothermically react with the molten metal, concrete, or other incompatible materials shall be repaired or discarded.

22.18.3.2.13 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

22.18.3.2.14 Extreme care shall be exercised in pouring metal castings, to avoid spillage.

22.18.3.2.15 All molds shall be thoroughly preheated before pouring.

22.18.3.2.16 Operators' Garments.

22.18.3.2.16.1 Operators in melting and casting areas where there is an opportunity for the operator to come into contact with molten metal shall wear flame-resistant clothing, high top safety shoes, and face protection.

22.18.3.2.16.2 Garments worn where molten metal is present shall have no exposed pockets or cuffs that could trap and retain metal.

22.18.3.3 Refining. (Reserved)

22.18.4 Powder Production.

22.18.4.1 Handling and Conveying of Powder.

22.18.4.1.1 Where powder is present, good housekeeping practices shall be maintained.

22.18.4.1.2 Powder shall be handled so as to avoid spillage and the creation of airborne dust.

22.18.4.1.3 Scoops, shovels, and scrapers used in the handling of powder shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

22.18.4.1.4 Each container for powders shall be conductive and covered while in storage or in transit.

22.18.4.1.5 When powders are being charged to or discharged from machines, the containers shall be bonded to the grounded machine.

22.18.4.1.6 When powder is being transferred between containers, the containers shall be bonded, and at least one of the containers shall be grounded.

22.18.4.2 Portable Containers.

22.18.4.2.1 In-plant transport of metal powders shall be done in covered conductive containers as described in 22.18.4.1.4.

22.18.4.3 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 22.9.4.3.2.1.

22.18.4.4 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 22.9.4.3.2.2.

22.18.4.5 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 22.9.6.15.

22.18.4.6 Powder Collection. Powder collection shall be in accordance with 22.9.4.3.5.

22.18.5 End Users of Powder.

22.18.5.1 Powder Handling and Use.

22.18.5.1.1 Scope. The provisions of 22.18.5 shall apply to operations including, but not limited to, the use of powder in the production of paste, flake powders, powdered metallurgy component manufacturing, fireworks and pyrotechnics, propellants, plasma spray coating, chemical processing, and refractories.

22.18.5.1.2 Storage. Dry powder and paste shall be stored in accordance with the provisions of 22.18.9.

22.18.5.1.3* Handling. The requirements of 22.18.5 shall apply to both regular and "nondusting" grades of powder, as well as to paste.

22.18.5.1.4 Where powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with Section 8.4 and 22.8.4.

22.18.5.1.5 Scoops, shovels, and scrapers used in the handling of powder and paste shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

22.18.5.1.6 Powered industrial trucks shall be selected in accordance with NFPA 505 and consistent with 9.6.8.

22.18.5.2 General.

22.18.5.2.1* Equipment shall be constructed to mitigate the potential for ignition of the powder.

22.18.5.2.2 A hazards analysis shall be performed for areas where powder is present to determine risk factors and appropriate controls.

22.18.5.2.3* Where the hazards analysis shows that controls are required to manage the risk of static generation and that static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear static-dissipative footwear or equivalent grounding devices.

22.18.5.2.4* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of powder.

22.18.5.2.5* Spark-resistant tools shall be used.

22.18.5.2.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

22.18.5.3 Powder Storage.

22.18.5.3.1 Daily supplies of powder shall be allowed to be stored in the production area.

22.18.5.3.1.1 The powder shall be stored in covered containers and shall be segregated from other combustible materials.

22.18.5.3.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

22.18.5.3.1.3 The containers shall be protected from damage.

22.18.5.3.2 Stacked Storage.

22.18.5.3.2.1 When powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

22.18.5.3.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate firefighting operations.

22.18.5.4 Dry Powder Handling.

22.18.5.4.1* Precautions shall be taken to prevent spills or dispersions that produce dust clouds.

22.18.5.4.2 Sintering furnaces that handle compacted powder shall be installed and operated in accordance with NFPA 86.

22.18.5.4.2.1 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

22.18.5.4.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

22.18.5.5 Handling of Wet Powder by End Users.

22.18.5.5.1 When water-wetted powder is air-dried at atmospheric pressure, the temperature shall not exceed 176°F (80°C).

22.18.5.5.2 When powders wetted with fluids other than water are air-dried, the temperature shall be governed by the characteristics of the fluid but shall not exceed 176°F (80°C).

22.18.5.5.3 When powders are dried under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature of the powder exceeds 176°F (80°C), the powder shall be cooled to less than 176°F (80°C) prior to exposure to air.

22.18.5.6 Heat Treatment and Passivation.

22.18.5.6.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of the powder.

22.18.5.6.2 Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54.

22.18.5.6.3 Furnaces shall comply with NFPA 86.

22.18.5.7* Personnel Safety Precautions.

22.18.5.7.1 The metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with that particular metal.

22.18.5.7.2 Access to metal-handling areas by unauthorized personnel shall not be permitted.

22.18.5.7.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

22.18.5.8 Powder Heat Treatment and Sintering.

22.18.5.8.1 After powder furnacing, the powder shall be passivated prior to exposure to air atmosphere.

22.18.5.8.2 Furnaced powder shall be cooled to 122°F (50°C) or less prior to starting passivation.

22.18.5.9* Heat Treatment and Sintering of Compacts.

22.18.5.9.1* Sintered compacts shall be cooled to 122°F (50°C) or less prior to removal from the furnace.

22.18.5.9.2 Sintered compacts shall be isolated from other combustible materials until their temperature has stabilized below 122°F (50°C).

22.18.5.10 Safety Precautions.

22.18.5.10.1 If the furnace's primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cool-down time period.

22.18.5.10.2 The alternative cooling system specified in 22.18.5.10.1 shall be activated automatically upon failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

22.18.6 Processing.

22.18.6.1 Machining and Operations.

22.18.6.1.1 Requirements for Machinery.

22.18.6.1.2 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

22.18.6.1.3* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

22.18.6.1.4 Bearings.

22.18.6.1.4.1* Ball or roller bearings shall be sealed against dust.

22.18.6.1.4.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal dust and shall have a lubrication program.

22.18.6.1.5 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

22.18.6.1.6 Permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal or other foreign objects can be introduced into the manufacturing operation.

22.18.6.1.7 Startup Operations. Before being placed into operation, all areas of processing machinery that will be in contact with combustible metal shall be free of the following:

- (1) Foreign objects and materials
- (2) Water, where combustible metal is reactive with water

22.18.6.2 Flake and Paste.

22.18.6.2.1 Machinery and Operations.

22.18.6.2.1.1* Wet Milling of Metal Powder. The requirements of 22.18.6.2.1.1(A) through 22.18.6.2.1.1(F) shall not apply to machining and rolling operations.

(A)* Where metal is added to a mill in the presence of a liquid that is chemically inert with respect to the metal, the milling shall be done in air in a vented mill or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

(B)* Where metal is slurried in tanks or processed in blenders or other similar equipment in the presence of a liquid that is chemically inert with respect to the metal, the operation shall be carried out in air or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

(C) The dew point of the atmospheres in 22.18.6.2.1.1(A) and 22.18.6.2.1.1(B) shall be maintained below the point where condensation occurs.

(D) Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes, a conductive lubricant, or other applicable means.

(E)* Ventilation in accordance with NFPA 30 shall be maintained in areas where flammable or combustible solvents are handled, particularly in areas where combustible metal dusts or powders are present.

(F) Solvent or slurry pumps shall be installed with controls that ensure that a flow exists and that the pumps run with safe operating temperatures.

22.18.6.2.2 Electrical Equipment.

22.18.6.2.2.1 When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

22.18.6.2.2.2* Wet solvent milling areas or other areas where ignitable (flammable or combustible liquids are present shall be classified, where applicable, in accordance with Article 500, 505, or 506 of *NFPA 70* with the exception of control equipment meeting the requirements of NFPA 496.

22.18.6.3 Plasma Spray Operations.

22.18.6.3.1 For plasma spray operations, media collectors, if used, shall be located at a distance from the point of collection to eliminate the possibility of hot metal particles igniting the filter media in the collector.

22.18.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

22.18.6.4 Transfer Operations.

22.18.6.4.1* Operations involving the transfer of combustible metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, and

buildings from the fire or dust explosion hazard produced by airborne suspensions of combustible metal dusts or powders.

22.18.6.4.2 Prevention of Fugitive Dust Accumulations. See 22.18.1.2.

22.18.6.5 Processing Recycled Material. The requirements of Section 22.19 shall apply to processes handling recycled metal that is in a combustible form.

22.18.7* Machining, Fabrication, Finishing, and Media Blasting.

22.18.7.1 Hot Work Operations.

22.18.7.1.1 Hot work operations in facilities covered by this chapter shall be in accordance with Section 8.5.

22.18.7.2 General Precautions.

22.18.7.2.1 Any equipment used for the machining, fabrication, or finishing of metal shall be dedicated to metal only and marked with a placard that reads as follows:

WARNING

Metal Only — Fire or Explosion Can Result with Other Metals.

22.18.7.2.2 Equipment producing metal in a combustible form shall be permitted to be used for other materials only when the system is thoroughly cleaned of all incompatible materials prior to and after its use.

22.18.7.3 Chip Production and Processing.

22.18.7.3.1 Machining and Sawing Operations.

22.18.7.3.2 Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal.

22.18.7.3.3 Sawing, grinding, and cutting equipment shall be grounded.

22.18.7.3.4 All metal chips, oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top containers dedicated to the specific metal only and removed daily, at a minimum, to a safe storage or disposal area.

22.18.7.3.5 Coolant.

22.18.7.3.5.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

22.18.7.3.5.2 The coolant shall be filtered on a continuous basis, and the collected solids shall not be allowed to accumulate in quantities greater than 5 gal (19 L) and shall be removed to a safe storage or disposal area.

22.18.7.4 Dust Collection. Dust collection shall be in accordance with 9.4.3 and 22.9.4.3.

22.18.8 Storage and Handling.

22.18.8.1 Storage of Combustible Metal Powder.

22.18.8.1.1 Buildings used to store metal powder shall be of noncombustible construction.

22.18.8.1.2 The use of automatic sprinklers in metal powder storage buildings shall be prohibited.

22.18.8.1.3 Metal powder shall be kept separated from other ordinary combustibles or incompatible materials.

22.18.8.1.4 Metal powder shall be stored in closed steel drums or other closed noncombustible containers.

22.18.8.1.5 Where the metal powder is reactive with water, metal-powder storage areas shall be kept dry.

22.18.8.1.6* Where metal powder in drums is stacked for storage, the maximum height shall not exceed 12 ft (3.7 m).

22.18.8.1.6.1 Storage drums shall be stacked in a manner that ensures stability.

22.18.8.1.6.2 Under no circumstances shall containers be allowed to topple over.

22.18.8.1.7* Storage of Other Metal Products.

22.18.8.1.7.1 Storage in quantities greater than 50 ft³ (1.4 m³) shall be separated from storage of other materials that are either combustible or in combustible containers by aisles with a minimum width equal to the height of the piles of metal products.

22.18.8.1.7.2 Metal products stored in quantities greater than 989 ft³ (28 m³) shall be separated into piles, each not larger than 989 ft³ (28 m³), with the minimum aisle width equal to the height of the piles but not less than 10 ft (3.1 m).

22.18.8.1.7.3* The storage area shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 989 ft³ (28 m³) is contained in a building of combustible construction
- (2) Where metal products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 30 ft (9 m) of the metal

22.18.8.2 Scrap Handling, Storage, and Disposal.

22.18.8.2.1 Storage of Combustible Scrap Metal.

22.18.8.2.1.1 The requirements of 22.18.8.2.1 shall apply to the storage of scrap metal in the form of solids, chips, turnings, swarf, or other fine particles.

22.18.8.2.1.2 Buildings used for the indoor storage of metal scrap shall be of noncombustible construction.

22.18.8.2.1.3 Scraps shall be kept well separated from other combustible materials.

(A) Scraps shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet.

(B) Outside storage of metal fines shall be permitted if such storage is separated from buildings or personnel and precautions are exercised to prevent the fines from becoming wet.

22.18.8.2.1.4* Wet metal scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

(A) Sources of ignition shall be kept away from the container vent and top.

(B) Containers shall not be stacked.

22.18.8.2.1.5 Storage of dry scrap in quantities greater than 50 ft³ (1.4 m³) [six 55 gal drums (six 208 L drums)] shall be

kept separate from other occupancies by fire-resistive construction or by an open space of at least 50 ft (15 m).

22.18.8.2.1.6 Buildings used for storage of dry scrap shall be well ventilated to avoid the accumulation of hydrogen in the event that the scrap becomes wet.

22.18.8.2.1.7 Solid metal scrap, such as clippings and castings, shall be stored in noncombustible bins or containers.

22.18.8.2.1.8 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid metal scrap.

22.18.8.2.1.9 The use of automatic sprinklers in metal-scrap storage buildings or areas shall be prohibited.

22.18.8.3 Recycling. (Reserved)

22.18.8.4 Chip Processing. (Reserved)

22.18.9 Fire and Explosion Prevention.

22.18.9.1 Fire and explosion prevention shall be in accordance with 22.9.9 and Section 22.10.

22.18.9.2 Control of Ignition Sources. (Reserved)

22.18.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 8.5.

22.18.9.4 Control of Combustible Materials. (Reserved)

22.18.9.5 Inspection, Maintenance, and Training.

22.18.9.5.1 Emergency Procedures. Emergency procedures shall be in accordance with Section 22.10.

22.18.9.5.1.1 Emergency procedures to be followed in case of fire or explosion shall be established.

22.18.9.5.1.2 All employees shall be trained in the emergency procedures.

22.18.10 Other. (Reserved)

22.19 Recycling and Waste Management Facilities

22.19.1* General Provisions.

22.19.1.1 Retroactivity. The requirements of Section 22.19 shall apply to new and existing recycling and waste management facilities that handle metals in combustible forms, including metal-only mixtures and mixtures containing metals.

22.19.1.2 A combustible metal or metal dust hazard shall be identified by testing in accordance with Chapters 4 and 5 and Section 22.5 prior to application of any of the provisions of Section 22.19.

22.19.1.3 For facilities recycling or providing treatment or disposal services, the requirements of Sections 22.6 through 22.10 shall also apply.

22.19.2 Recycling and Waste Management of Combustible Metal — Collection, Storage, and Handling of Fines Generated During Scrap Receiving, Storage, Recycling, and Waste Treatment.

22.19.2.1 Receiving Criteria. Incoming material shall be inspected for acceptance criteria.

22.19.2.1.1 Acceptance criteria for combustible metals being recycled shall be established by the recycler. The acceptance criteria shall include the following as a minimum:

- (1) Acceptable packaging
- (2) Forms
- (3) Identification/manifest (DOT shipping papers)
- (4) Required protection against foreign material
- (5) Identification and segregation of any radiation/contamination of materials
- (6) SDS
- (7) Certificate of insurance
- (8) Authorized signature of acceptance of material
- (9) Internal quality control procedures
- (10) Incoming material analysis plan
- (11) Nonconforming material plan

22.19.2.1.2 Acceptance criteria for combustible metals offered for waste disposal shall be established by communication between the generator and waste disposal facility and shall include the following as a minimum:

- (1) Acceptable packaging
- (2) Waste profile specifying the form of the material and any changes in form or concentration from previous shipments
- (3) Waste analysis plan
- (4) Identification and concentration range of constituents
- (5) Required protection against physical hazards including combustibility, pyrophoric, and water reactivity
- (6) Identification and segregation from incompatible materials if stored
- (7) SDS
- (8) Nonconforming material plan

22.19.2.1.3 The acceptance criteria shall be documented and available for review by the AHJ.

22.19.2.2 Rejected Material.

22.19.2.2.1 Combustible metal only and mixtures containing combustible metals that cannot be stored, handled, or processed by the receiving facility shall be rejected.

22.19.2.2.2 Rejected material shall be returned to the supplier within 5 working days or days or engineering controls, or alternate methods for the safe disposal of the rejected material shall be implemented in accordance with local, state, and federal regulations.

22.19.2.2.3 Rejected material shall be labeled and segregated in an area identified for storage of rejected or nonconforming material in accordance with the nonconforming materials plan.

22.19.3 Storage of Combustible Metals for Recycling and Waste Management.

22.19.3.1 Combustible metal-only mixtures, mixtures containing combustible metals, and materials that can potentially produce combustible metal or metal dust as a result of normal handling shall include provisions for the handling of any possible resulting metals as defined in this section.

22.19.3.2* Containers and areas where combustible metals are stored shall be labeled or identified as to the type of metal stored, form of metal, and date of receipt.

22.19.3.3 A tracking system shall be implemented for inventory control and shall include the following:

- (1) Type and form of combustible metal
- (2) Storage location
- (3) Date of receipt
- (4) Other hazards including but not limited to reactivity with water, pyrophoric, and compatibility

22.19.3.4 The tracking records shall be available for inspection by the authority having jurisdiction.

22.19.3.5 Area and container labels or identification shall reference the appropriate safety data sheets (SDSs) on file.

22.19.3.6 Buildings used for the indoor storage of combustible metal shall be of noncombustible construction and shall meet the requirements of 22.9.3.6.

22.19.3.7 Solid combustible metals, such as clippings and castings, shall be stored in noncombustible bins or containers.

22.19.3.8 Combustible metals shall be separated from other combustible materials that would provide additional fuel in the event of a fire such as wood pallets and corrugated cardboard.

22.19.3.9 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid recycled combustible metal.

22.19.3.10* Combustible metals delivered for recycling or waste disposal that are stored on-site shall be identified as wet or dry.

22.19.3.11 Dry Combustible Metals Storage. Combustible metals in a dry condition shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet.

22.19.3.11.1 Buildings used for storage of dry combustible metal shall be well ventilated to avoid the accumulation of hydrogen in the event that the combustible metal becomes wet.

22.19.3.11.2 When the recyclable or waste material has the potential for water reactivity because of the specific combustible metal content, provisions shall be made to keep it dry.

22.19.3.11.3 Outside storage of dry combustible metals shall be permitted if such storage is separated from buildings or personnel.

22.19.3.11.4 Storage of dry combustible metals in quantities greater than 50 ft³ (1.4 m³) [six 55 gal drums (six 208 L drums)] shall be kept separate from other occupancies by fire-resistive construction or by an open space of at least 50 ft (15 m).

22.19.3.11.5 Quantity Separation Distance. (Reserved)

22.19.3.12 Wet Combustible Metals Storage.

22.19.3.12.1 Wet combustible metals shall be stored at an outside location identified for that use.

22.19.3.12.2 Open flames and sparks shall be kept 50 ft (15 m) away from the container unless a hot-work permit allows an open flame within 50 ft (15 m).

22.19.3.12.3* Combustible metals that are received wet shall be kept under water in a covered and vented container.

22.19.3.12.4 Containers of wet combustible metals shall not be stacked.

22.19.3.12.5 Quantity Separation Distance. (Reserved)

22.19.3.13 Container Limits.

22.19.3.13.1 Where drums or other containers are used for storage of dry combustible metals, storage shall be limited to a height that would require no more than three movements using available equipment to remove a stack, and no stack shall exceed 10 ft (3.1 m) in height.

22.19.3.13.2 The maximum weight of any material container and/or pallet shall be capable of being moved by the available equipment.

22.19.3.13.3 Stacked storage shall be arranged to ensure stability.

22.19.3.13.3.1 Aisles shall be provided for maneuverability of material handling equipment, for accessibility, and to facilitate firefighting operations.

22.19.4 Sample Identification and Collection for Metals in a Combustible Form.

22.19.4.1 When the combustibility of a metal or mixture is not known or reported on the waste manifest sheet, the metal shall be tested as specified in Section 22.5 to determine whether it is a combustible metal.

22.19.4.2 For waste disposal, the waste manifest shall disclose the type of metal(s) by name and if they are in a combustible form.

22.19.4.3* In recycling facilities where combustible metals are processed, samples shall be collected that represent a “worst case” scenario.

22.19.4.4 Each site shall develop a sampling strategy and protocol to ensure that samples are collected in all areas where combustible metals and metal dust can reasonably be assumed to be present. The following shall be considered in developing the sampling strategy:

- (1) All processes that produce dust (e.g., UBC processing; remelt and casting; alloying molten metal; aluminum scrap chopping, conveyance, shredding, handling, and sawing; etc.)
- (2) Horizontal surfaces on and around the process identified.
- (3) Various heights on the equipment and in the building. Note: lighter, small particle-sized dust tends to collect higher in the structure.
- (4) Recessed or hidden areas where dust could have collected,
- (5) Worst-case process situations where possible. For example, higher magnesium content has been shown to have higher energy potential.
- (6) Inside bins, hoppers, baghouses, cyclones, ductwork, etc., used to store, collect, and convey materials.

22.19.4.5 Samples collected shall be promptly submitted for testing as dust tends to oxidize over time.

22.19.5 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 8.6.

22.19.6 Reactivity.

22.19.6.1 It shall be the responsibility of the recycling and waste management facilities to evaluate processes and materials for potentially dangerous reactions that could occur in the course of their operations.

22.19.6.2 Contact with Water.

22.19.6.2.1* Water leakage inside or into any building where the water can contact metal-reactive materials shall be prevented to avoid possible spontaneous heating.

22.19.6.3 Thermite Reaction.

22.19.6.3.1* Caution shall be exercised in the mixing of metal fines and metal oxides [e.g., iron oxide (rust)].

22.19.7 Management of Change. Management of change shall be in accordance with Section 8.11.

22.19.8 Facility Design Requirements.

22.19.8.1 Building Construction. Building construction shall be in accordance with 22.9.3.

22.19.8.2 Electrical Classification.

22.19.8.2.1 Electrical classification shall be in accordance with 9.6.5.

22.19.8.3 Hazards Analysis. Hazards analysis shall be in accordance with Chapter 7 and Section 22.7.

22.19.9 Emergency Preparedness.

22.19.9.1 Procedures.

22.19.9.1.1 Emergency procedures shall be established to address fire and explosion events in accordance with 22.10.2.

22.19.9.1.2 The emergency procedures shall be documented.

22.19.9.1.3 In cases where a process hazard analysis indicates that application of low-velocity water can be beneficial for the preservation of life and/or property, the provisions of 22.9.9.3.5 shall be superseded.

22.19.9.1.3.1 If the determination is made to apply low-velocity water to a fire, the following shall be observed:

- (1) Care is to be taken to prevent the formation of a dust cloud.
- (2) The area is to be determined to be well ventilated, and/or ventilation should be maximized prior to water application, in order to prevent the accumulation of hydrogen gas.
- (3) After extinguishment, the area is to be cleaned of all wetted powder, paste, or slurry, and ventilation should be continued throughout this process.

22.19.9.2* Training.

22.19.9.2.1 All employees shall be trained in the emergency procedures and the hazards of combustible metals.

22.19.9.2.2 Training shall be documented and available for inspection by the authority having jurisdiction.

22.19.10 Processing.

22.19.10.1 Control of ignition sources shall be in accordance with Section 9.6 and 22.9.6.

22.19.10.1.1 Recyclers and waste generators or waste brokers shall determine the combustibility and explosivity characteristics of any waste, by-product, intermediate, or final material generated as a result of on-site processing.

22.19.10.1.2* Documentation of the determination in 22.19.10.1.1 shall be maintained and available for review by the authority having jurisdiction.

22.19.10.1.3 For all processing of recycled combustible metals for which there are specific chapters, the requirements of those chapters shall apply in addition to the requirements of Section 22.19.

22.19.10.1.4 For all other recycled combustible metal and alloy processing, the requirements of Section 22.18 shall also apply.

22.19.10.1.5 Ignitable (flammable or combustible) liquids resulting from recycling of combustible metals shall be handled and stored in accordance with NFPA 30.

22.19.10.1.6 Hazardous materials resulting from recycling of combustible metals shall be handled and stored in accordance with local, state, and federal regulations and NFPA 1.

22.19.10.1.7 Sumps and trenches in manufacturing and process areas should be cleaned at the end of the work shift to prevent accumulation of fines and incompatible materials.

22.19.10.2 Machining and Operations.**22.19.10.2.1 Requirements for Machinery.**

22.19.10.2.2 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

22.19.10.2.3 All machinery and equipment shall be installed in accordance with *NFPA 70*.

22.19.10.2.4* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

22.19.10.2.5 Bearings.

22.19.10.2.5.1* Ball or roller bearings shall be sealed against dust.

22.19.10.2.5.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal and metal dust and shall have a lubrication program.

22.19.10.2.5.3 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

22.19.10.2.5.4 Permanent magnetic separators, pneumatic separators, or screens shall be installed ahead of mills, stamps, or pulverizers wherever there is any possibility that tramp metal

or other foreign objects can be introduced into processing related operations.

22.19.10.2.5.5 All areas of processing machinery that will be in contact with combustible metal materials shall be free of foreign objects, foreign material, and water before being placed in operation.

22.19.10.3 Transfer Operations.

22.19.10.3.1* Operations involving the transfer of combustible metals or metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, and buildings from the fire or dust explosion hazard produced by airborne suspensions of metals in a combustible form.

22.19.10.3.2 The container shall be grounded and bonded and nonsparking tools shall be used.

22.19.10.3.3 Equipment producing metal in a combustible form shall be permitted to be used for other materials only when the system is thoroughly cleaned of all incompatible materials prior to and after its use.

22.19.10.4 Electrical Equipment.

22.19.10.4.1 All electrical wiring and equipment shall be in accordance with Section 9.6 and 22.9.6.

22.19.10.5 Chip Processing. (Reserved)**22.19.10.6 Machining and Sawing Operations.**

22.19.10.6.1* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal being processed.

22.19.10.6.2* Sawing, grinding, and cutting equipment shall be grounded.

22.19.10.7 Coolant.

22.19.10.7.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

22.19.10.7.2 The coolant shall be filtered on a continuous basis, and the collected solids shall not be allowed to accumulate in quantities greater than 19 L (5 gal) and shall be removed to a safe storage or disposal area.

22.19.10.8 Dust Collection.

22.19.10.8.1 Dust collection shall be in accordance with 9.4.3 and 22.9.4.3.

22.19.11 Fire and Explosion Prevention.

22.19.11.1 The requirements of 22.9.9 and Section 22.10 shall apply.

22.19.11.2 Housekeeping.

22.19.11.2.1 The requirements of Section 8.4 and 22.8.4 shall apply.

22.19.11.3 Control of Metals in a Combustible from Finishing Operations.

22.19.11.3.1 It shall be permissible to use an open top container to collect metal chips, lathe turnings, and swarf if the container is grounded and has shelter to prevent water entrainment.

22.19.11.3.2 If the containers collecting metal chips, lathe turnings, and swarf are to be sent for disposal, the specific metal and form of the waste shall be documented.

22.19.11.4 Inspection, Maintenance, and Training.

22.19.11.4.1 Regular inspections shall be conducted to detect the accumulation of excessive metals in a combustible form on

any portions of buildings or machinery not regularly cleaned in daily operations.

22.19.11.4.2 Records shall be kept of the inspections conducted in 22.19.11.4.

Chapter 23 Sulfur

23.1 Administration.

23.1.1 Scope.

23.1.1.1* This chapter addresses the processing and handling of sulfur in solid or molten form.

23.1.1.2 This chapter shall not apply to the mining of sulfur, recovery of sulfur from process streams, or transportation of sulfur.

23.1.1.3 This chapter shall not apply to the recovery of sulfur from process streams, such as sour gas processing or oil refinery operations, and all its encompassed processes and operations, which include block melting, degassing, and forming.

23.1.2 Reserved.

23.1.3 Application. This chapter shall modify and augment the requirements of Chapters 1 through 10 and Chapter 25. Where conflicts exist, refer to Section 1.6.

23.2 Reserved.

23.3 Reserved.

23.4 General Requirements.

23.4.1 General. Sections 23.4 through 23.9 shall apply to the handling and processing of solid sulfur.

23.5 Reserved.

23.6 Reserved.

23.7 Dust Hazards Analysis (DHA).

23.7.1 General Requirements. Those portions of the facility where dust accumulations exist shall be evaluated to determine if a dust explosion hazard or flash fire hazard exists.

23.7.2 Reserved.

23.7.3 Methodology.

23.7.3.1 General.

23.7.3.1.1 Building, rooms, compartments, and other interior spaces shall be assessed in accordance with 23.7.3.1.2 and either 23.7.3.5 or 23.7.3.6, unless the colors of the surfaces underlying the dust accumulations are readily discernible.

23.7.3.1.2 Dust explosion hazard areas and dust flash fire hazard areas shall be deemed to exist where dust clouds of a hazardous concentration exist.

23.7.3.1.3 All dust accumulated on structures above the lowest footprint shall be evaluated as if accumulated on the lowest footprint.

23.7.3.1.4 Dust accumulation amounts shall reflect the conditions that exist just prior to routinely scheduled cleaning and shall not include short-term accumulations cleaned in accordance with Chapter 7.

23.7.3.1.5 Personnel exposed to a dust explosion hazard or dust flash fire hazard shall be protected in accordance with Section 8.6.

23.7.3.1.6 A dust explosion hazard area shall be deemed to exist in process equipment where all the following conditions are possible:

- (1) Combustible dust is present in sufficient quantity to cause rupture of the vessel if suspended and ignited.
- (2) A means of suspending the dust is present.

23.7.3.2 Reserved.

23.7.3.3 Reserved.

23.7.3.4 Reserved.

23.7.3.5* Layer Depth Criterion Method.

23.7.3.5.1* For materials with bulk density less than 75 lb/ft³ (1200 kg/m³), the layer depth criterion of 1/32 in. (0.8 mm) shall be permitted to be increased according to Equation 23.7.3.5.1:

[23.7.3.5.1]

$$\text{Allowable Thickness (in.)} = \frac{\left(\frac{1}{32} \text{ in.}\right)(75 \text{ lb/ft}^3)}{\text{bulk density (lb/ft}^3\text{)}}$$

23.7.3.5.2 The footprint area shall be determined as the lesser of the building/room area or 21,500 ft² (2000 m²).

23.7.3.5.3* A dust explosion hazard and dust flash fire hazard shall be deemed to exist in any building or room where either of the following conditions exists:

- (1) The total area of dust accumulations exceeding the layer depth criterion is greater than 5 percent of the footprint area.
- (2) The total volume of dust accumulations is greater than the layer depth criterion multiplied by 5 percent of the footprint area.

23.7.3.6* Mass Method. Unless the method in 23.7.3.5 is being used, dust explosion hazard areas and dust flash fire hazard areas shall be deemed to exist when the total accumulated dust on any surfaces exceeds the thresholds calculated in 23.7.3.6.1 or 23.7.3.6.2, respectively.

23.7.3.6.1* The threshold dust mass establishing a building or room as a dust explosion hazard area, $M_{\text{basic-exp}}$ shall be determined according to Equation 23.7.3.6.1.

[23.7.3.6.1]

$$M_{\text{basic-exp}} = 0.01 \cdot A_{\text{floor}} \cdot H$$

where:

$M_{\text{basic-exp}}$ = threshold dust mass (kg) based on building damage criterion

A_{floor} = lesser of the enclosure floor area (m²) or 2000 m²

H = lesser of the enclosure ceiling height (m) or 12 m

23.7.3.6.2* The threshold dust mass establishing a building or room as a dust flash fire hazard area, $M_{basic - fire}$, shall be determined according to Equation 23.7.3.6.2.

[23.7.3.6.2]

$$M_{basic - fire} = 0.05 \cdot A_{floor}$$

where:

$M_{basic - fire}$ = threshold dust mass (kg) based on personnel fire exposure criterion

A_{floor} = lesser of the enclosure floor area (m²) or 2000 m²

23.8 Management Systems.

23.8.1 Retroactivity. The requirements of Chapter 8 and Section 23.8 shall be applied retroactively to new and existing facilities and processes where the DHA has determined that a combustible dust or particulate solid fire, flash fire, or explosion hazard exists, or where an analysis of the molten sulfur handling indicates that a fire, flash fire, or explosion hazard exists.

23.8.2 Reserved.

23.8.3* Operating Procedures and Practices. Operation and maintenance of all size reduction machinery shall be under supervision.

23.8.4 Housekeeping.

23.8.4.1 Reserved.

23.8.4.2 Methodology.

23.8.4.2.1 Procedure.

23.8.4.2.1.1 Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

23.8.4.2.1.2* Sweeping shall be the preferred method.

23.8.4.2.1.3 Vacuuming shall be permitted.

23.8.4.2.2 Reserved.

23.8.4.2.3 Reserved.

23.8.4.2.4 Reserved.

23.8.4.2.5 Reserved.

23.8.4.2.6* Compressed Air Blowdown Method. (Reserved)

23.8.4.3 Reserved.

23.8.4.4 Reserved.

23.8.4.5 Reserved.

23.8.4.6* Frequency and Goal. See 8.4.6.

23.8.5 Reserved.

23.8.6 Reserved.

23.8.7 Inspection, Testing, and Maintenance

23.8.7.1 Reserved.

23.8.7.2 Specific Equipment Maintenance.

23.8.7.2.1 Maintenance of material-feeding devices shall comply with 25.8.7.2.1.

23.8.7.2.2 Maintenance of fans and blowers (air-moving devices) shall comply with 25.8.7.2.2.

23.8.7.2.3 Maintenance of AMS shall comply with 25.8.7.2.3.

23.8.7.2.4 Maintenance of fire and explosion protection systems shall comply with 25.8.7.2.5.

23.8.8 Reserved.

23.8.9 Contractors. Contractors involved in the commissioning, repair, or modification of explosion protection equipment shall be qualified as specified in NFPA 69 when such devices are employed.

23.8.9.1 Reserved.

23.8.9.2 Reserved.

23.8.9.3* Contractor Training. Documentation shall be maintained detailing the training that was provided and who received it.

23.9 Hazard Management: Mitigation and Prevention.

23.9.1 Reserved.

23.9.2 Reserved.

23.9.3 Building Design.

23.9.3.1 Construction.

23.9.3.1.1* Floor-ceiling assemblies, roof assemblies, and load-bearing walls that are exposed to dust explosion hazards shall be designed so as to preclude failure during an explosion. (See NFPA 68.)

23.9.3.1.2 Buildings or enclosures containing a dust explosion hazard area shall be constructed with deflagration venting designed in accordance with NFPA 68.

23.9.3.1.3 Building Construction Requirements for Housing Size Reduction Machinery.

23.9.3.1.3.1 Where compression-style size reduction equipment is located outdoors, it shall be permitted to transfer reduced material in enclosed downstream equipment, provided either of the following conditions exists:

- (1) The transferred material is continuously wetted with water sufficient to prevent ignition.
- (2) An inert gas isolation system is provided between the compression-style size reduction equipment and the enclosed downstream equipment.

23.9.3.1.3.2* Where size reduction machinery is located in an enclosed or partially enclosed space, that space shall be segregated from other areas by noncombustible walls designed to withstand the force of a vented sulfur dust explosion. (See NFPA 68.)

23.9.3.2 Building or Building Compartment Protection.

23.9.3.2.1 Reserved.

23.9.3.2.2 Fire Resistance Rating.

23.9.3.2.2.1* Interior stairs and elevators shall be enclosed in shafts designed to prevent the migration of dust and that have a minimum fire resistance rating in accordance with Section 8.6 of NFPA 101.

23.9.3.2.2.2* Doors that are the automatic-closing or self-closing type and that have a minimum fire protection rating of 1 hour shall be provided at each landing.

23.9.3.2.2.3 Stairs, elevators, and manlifts that serve only open-deck floors, mezzanines, and platforms shall not be required to be enclosed.

23.9.3.2.3 Protection of Openings and Penetrations.

23.9.3.2.3.1 Where floors, walls, ceilings, and other partitions have been erected to control the spread of deflagrations, penetrations in these structures shall be sealed dusttight in normal operation and protected to maintain their fire resistance rating and physical integrity in a deflagration.

23.9.3.2.3.2 Openings in fire walls and in fire barrier walls shall be protected by self-closing fire doors that have a fire resistance rating equivalent to the wall design.

23.9.3.2.3.3 Fire doors shall be installed according to NFPA 80 and shall normally be in the closed position.

23.9.3.2.3.4 All pathways between the space used for size reduction and the rest of the building shall be from the outside or via indirect means as described in 23.9.3.2.3.5.

23.9.3.2.3.5* Indirect pathways through segregating walls by means of vestibules or stairways shall be permitted, provided the wall opening to the size reduction area is protected by an automatic-closing fire door suitable for 3-hour openings, and the opening into the vestibule or stairway is protected by an automatic-closing fire door suitable for 2-hour openings.

23.9.3.2.3.5.1 The two automatic-closing fire doors in 23.9.3.2.3.5 shall be installed at right angles to each other.

23.9.3.2.3.5.2 Both fire doors in 23.9.3.2.3.5 shall be installed in accordance with NFPA 80.

23.9.3.3 Life Safety. Means of egress shall comply with NFPA 101.

23.9.4 Equipment Design.

23.9.4.1 Reserved.

23.9.4.2 Reserved.

23.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

23.9.4.3.1 Reserved.

23.9.4.3.2 Specific Requirements for Pneumatic Conveying Systems. Unless the conveying system is inerted in accordance with 23.9.8.2(1), pneumatic conveying of sulfur shall not be permitted.

23.9.4.3.3 Specific Requirements for Dust Collection Systems.

23.9.4.3.3.1 Manifoldd branches serving equipment presenting a deflagration hazard shall be isolated in accordance with 9.8.3.

23.9.4.3.3.2* Dust collection ducts from a single piece of equipment or from multiple pieces of equipment interconnected on the same process stream shall be permitted to be manifolded without explosion isolation on the branches.

23.9.4.3.4 Specific Requirements for Centralized Vacuum Cleaning Systems. Dust collection ducts for centralized

vacuum cleaning systems shall be permitted to be manifolded without explosion isolation on the branches.

23.9.4.4 AMS.

23.9.4.4.1 Reserved.

23.9.4.4.2 Reserved.

23.9.4.4.3 Reserved.

23.9.4.4.4 Reserved.

23.9.4.4.5 Reserved.

23.9.4.4.6 Reserved.

23.9.4.4.7 AMS Construction. Hopper bottoms shall be sloped, and the discharge conveying system shall be designed to handle the maximum material flow attainable from the system.

23.9.4.5 Reserved.

23.9.4.6 Reserved.

23.9.4.7 Reserved.

23.9.4.8 Reserved.

23.9.4.9 Reserved.

23.9.4.10 Size Reduction.

23.9.4.10.1 Where size reduction machinery is located in an enclosed or partially enclosed space, that space shall be used only for the size reduction process and the filling of containers with the reduced material when size reduction of sulfur is in progress.

23.9.4.10.2* Containers shall be removed from the area as soon as possible after being filled.

23.9.4.11 Reserved.

23.9.4.12 Reserved.

23.9.4.13 Mechanical Feeding Devices. Mechanical feeding devices shall comply with 25.9.4.13.

23.9.4.14 Bucket Elevators. Bucket elevators shall comply with 25.9.4.14.

23.9.4.14.1 Nonferrous buckets for bucket elevators shall be used where they are housed in ferrous casings.

23.9.4.14.2* Aluminum buckets for bucket elevators shall not be used where they are housed in ferrous casings.

23.9.4.14.3 Ferrous buckets for bucket elevators shall be permitted to be used with ferrous casings, provided that an inert gas system meeting the requirements of 23.9.8.2(1) is used.

23.9.4.15 Conveyors and Spouts.

23.9.4.15.1* Only conveyors or spouts with isolation devices, such as rotary valves designed to prevent deflagration propagation in accordance with NFPA 69 shall be permitted to pass through segregating walls between size reduction rooms and adjacent spaces.

23.9.4.15.2 Conveyors used to feed or discharge sulfur to or from size reduction machinery shall be in dusttight housings.

23.9.4.15.3 Each pulverizer shall have a separate and self-contained system.

23.9.4.15.4 Enclosed conveyors shall comply with 25.9.4.15.

23.9.4.16 Mixers and Blenders. Mixers and blenders shall comply with 25.9.4.16.

23.9.4.17 Reserved.

23.9.4.18 Reserved.

23.9.4.19 Inert Gas Systems.

23.9.4.19.1 Size reduction equipment shall not be operated without the use of an inert gas system meeting the requirements of NFPA 69.

23.9.4.19.1.1 Where the pulverized sulfur is removed from the machinery by blower or exhaust systems, inert gas protection shall extend to all piping and collectors.

23.9.4.19.1.2* The inert gas system shall be equipped with sampling and recording instruments to obtain a reliable and continuous analysis of the inert atmosphere in that part or parts of the machinery where the inert atmosphere is normally weakest.

23.9.4.19.1.3 Provisions shall be made for automatically shutting down the size reduction machinery if the oxygen content of the atmosphere inside the inerted equipment rises above the maximum levels stated in 23.9.8.2(1).

23.9.4.19.2 Use of inert gas shall not be required for compression-style size reduction equipment.

23.9.4.19.3 Impact-style size reduction equipment shall be permitted to be operated without inert gas protection if the following requirements are met:

- (1) The feed and discharge shall be provided with isolation devices, such as rotary valves designed in accordance with NFPA 69.
- (2) The isolation devices and all machinery between them shall be capable of withstanding an overpressure of 100 lb/in.² (690 kPa).
- (3) An inspection of the machinery shall be performed at least once per shift during operation to detect abnormalities in operating conditions.

23.9.4.19.4* Attrition-style size reduction equipment shall be permitted to be operated without inert gas protection if the following requirements are met:

- (1) Manually operated valves shall be installed at each machine for control of feed and air lines.
- (2)* The equipment shall be under supervision during operation and shall be shut down for detailed inspection and any necessary cleaning when abnormalities in operation indicate the possibility of fire within the machine.
- (3) All valves shall be closed before opening the machine.

23.9.5 Dust Control.

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

23.9.5.2 The dust shall be conveyed to AMSs.

23.9.6 Ignition Source Control. The requirements of 23.9.6.7 and 23.9.6.13 shall be applied retroactively.

23.9.6.1 Reserved.

23.9.6.2 Reserved.

23.9.6.3 Hot Surfaces. Unprotected hot surfaces, such as steam lines, that can attain temperatures high enough to melt and ignite sulfur dust shall not be exposed in enclosures housing sulfur processing equipment.

23.9.6.4 Reserved.

23.9.6.5 Reserved.

23.9.6.6* Electrostatic Discharges. All machinery, conveyors, housings, and collectors shall be thoroughly bonded and grounded with a resistance of less than 1 megaohm (1.0×10^6 ohms) to ground to prevent the accumulation of static electricity.

23.9.6.6.1 Reserved.

23.9.6.6.2 Maximum Particulate Transport Rates. Maximum particulate transport rates shall comply with 25.9.6.6.2.

23.9.6.6.3 Reserved.

23.9.6.6.4* Flexible Intermediate Bulk Containers (FIBCs).

23.9.6.6.4.1 The requirements of 23.9.6.6.4.2 through 23.9.6.6.4.4 shall be applied retroactively.

23.9.6.6.4.2* Dispensing solid sulfur from intermediate bulk containers shall only be performed under the following conditions:

- (1) A conductive (i.e., metallic) rigid intermediate bulk container (RIBC) shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmospheres provided the RIBC is electrically grounded with a resistance less than 1 megaohm (1.0×10^6 ohms) to ground.
- (2)* A Type C FIBC shall be permitted to be used for dispensing into any flammable vapor, gas, dust, or hybrid atmosphere for which the FIBC has been tested and found suitable, provided the FIBC is electrically grounded with a resistance less than 1 megaohm (1.0×10^6 ohms) to ground.
- (3)* A Type D FIBC shall be permitted to be used for dispensing into flammable vapor, gas, dust, or hybrid atmospheres for which the FIBC has been tested and found suitable.
- (4)* Type A FIBC, Type B FIBC, or insulating RIBCs shall not be permitted to be used for solid sulfur applications, processes, or operations unless a documented risk assessment assessing the electrostatic hazards, including the potential presence of hydrogen sulfide, is acceptable to the authority having jurisdiction.

23.9.6.6.4.3* FIBCs that are listed or tested by a recognized testing organization and are shown not to ignite flammable atmospheres, including hydrogen sulfide, during transfer shall be permitted to be used.

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

23.9.6.6.5 Rigid Intermediate Bulk Containers (RIBCs). See requirements for RIBCs in 23.9.6.6.4.

23.9.6.7 Open Flames. Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be

permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

23.9.6.8 Reserved.

23.9.6.9 Reserved.

23.9.6.10 Reserved.

23.9.6.11 Friction and Impact Sparks.

23.9.6.11.1 Floor sweepings shall not be returned to any machine.

23.9.6.11.2* Foreign materials, such as tramp metal, that are capable of igniting sulfur being processed shall be removed from the process stream by one of the following methods:

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

23.9.6.11.3 All machinery shall be installed and maintained in such a manner that the possibility of frictional sparks is minimized.

23.9.6.11.4 Interlocking controls shall be installed to stop the feed if the machinery stops or if the fans or blowers stop for any reason.

23.9.6.12 Reserved.

23.9.6.13 Reserved.

23.9.6.14* Electrical Systems.

23.9.6.14.1 All electrical equipment and installations shall comply with the requirements of *NFPA 70*.

23.9.6.14.2* Hazardous (classified) areas that are identified shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

23.9.6.15 Heating. Heating shall be by indirect means.

23.9.6.16 Shovels. Where shovels are used to handle sulfur dust, they shall be nonferrous and spark resistant.

23.9.7 Reserved.

23.9.8 Explosion Prevention and Protection.

23.9.8.1 Reserved.

23.9.8.2* Equipment Protection. The design of explosion protection for equipment shall incorporate one or more of the following methods of protection:

- (1) Oxidant concentration reduction in accordance with NFPA 69 and 23.9.4.19 of this chapter
- (2) Deflagration venting in accordance with NFPA 68
- (3) Deflagration pressure containment in accordance with NFPA 69
- (4) Deflagration suppression systems in accordance with NFPA 69

23.9.8.2.1 For the method in 23.9.8.2(1), under normal operating conditions, the limiting oxidant concentration (LOC) shall be permitted to be as follows:

- (1) 12.0 percent where carbon dioxide is used as the inert

- (2) 9.3 percent where nitrogen is used as the inert

23.9.8.2.2 Dilution with a noncombustible dust to render the mixture noncombustible shall not be permitted.

23.9.8.2.3 Deflagration venting through a dust retention and flame-arresting device shall not be permitted unless the device is listed for use with sulfur.

23.9.8.3* Equipment Isolation.

23.9.8.3.1 Isolation of Equipment. Isolation devices shall not be required where oxidant concentration in the connected equipment has been reduced in accordance with 23.9.8.2(1) and the general requirements of NFPA 69.

23.9.8.3.2* Isolation of Upstream Areas. Where an explosion hazard exists, isolation devices shall be provided to prevent deflagration propagation between connected equipment in accordance with NFPA 69.

23.9.9 Fire Protection.

23.9.9.1 General.

23.9.9.1.1 Where the owner/operator chooses to assign an industrial fire brigade to respond to plant emergencies, the brigade shall meet the requirements of NFPA 600.

23.9.9.1.2* Steam and inert gases shall be permitted to be used as extinguishing agents for tightly closed containers provided that the sulfur dust is not disturbed.

23.9.9.1.3 In all cases, it shall be made certain that the fire is completely extinguished before disturbing the dust and that the sulfur has cooled sufficiently to prevent reignition.

23.9.9.1.4* When processing equipment is opened for cleaning following an ignition, the feed, discharge, and other openings shall first be closed by suitable metal valves or gates.

23.9.9.2 Reserved.

23.9.9.3 Reserved.

23.9.9.4 Hose, Standpipes, Hydrants, and Water Supply.

23.9.9.4.1 Reserved.

23.9.9.4.2* Nozzles. It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible with the nozzles specified in 9.9.4.2.1.

23.10 Reserved.

23.11 Handling of Liquid Sulfur at Normal Handling Temperatures.

23.11.1* General. Section 23.11 shall apply to the handling of liquid sulfur in the temperature range of 246°F to 309°F (119°C to 154°C).

23.11.2 Detection of Unsafe Conditions.

23.11.2.1* Devices for measuring the concentration of combustible gas in the atmosphere over liquid sulfur shall be designed for operation in atmospheres containing hydrogen sulfide.

23.11.2.2 Instruments used for detecting explosive atmospheres shall be capable of measuring the lower explosive limit

of hydrogen sulfide, since it is the primary gas evolved from sulfur that can contribute to an explosive atmosphere.

23.11.2.3 Operations shall be discontinued whenever instruments show a combustible gas concentration of 35 percent or more of the lower explosive limit in the gas space of liquid sulfur containers.

23.11.2.4 Operations shall not be resumed until the instruments indicate a concentration of 15 percent or less of the lower explosive limit.

23.11.3 Equipment Design.

23.11.3.1 Liquid sulfur storage tanks shall be designed with fill lines that extend to near the tank bottom so that the incoming sulfur enters the tank below the surface of the sulfur in the tank, thereby minimizing agitation and release of hydrogen sulfide.

23.11.3.2 Vent Systems.

23.11.3.2.1 Covered storage tanks shall be provided with heated vent systems to provide natural venting of hydrogen sulfide.

23.11.3.2.2 Vent systems shall be maintained at a temperature above the melting temperature of sulfur.

23.11.3.3* Bonding and Grounding.

23.11.3.3.1 Sulfur lines and storage tanks shall be bonded and grounded with a resistance of less than 1 megaohm (1.0×10^6 ohms) to ground to prevent accumulation of static electricity.

23.11.3.3.2 Grounding connections shall be provided for the bonding of liquid sulfur tanks and tank cars being loaded or unloaded.

23.11.3.4* In pits or sections of tanks used for melting sulfur, and in liquid storage tanks that are regularly emptied, cooled, and exposed to air (moisture), the sulfur level shall be maintained above the heating coils.

23.11.3.5* All electrical wiring and equipment installed in areas handling liquid sulfur shall meet the requirements of Article 501 of *NFPA 70*.

23.11.4 Open Flames and Sparks. The requirements of 23.11.4.1 through 23.11.4.3 shall be applied retroactively.

23.11.4.1 Smoking shall be permitted only in designated areas.

23.11.4.2 Activities involving open flames, such as cutting or welding, heat, or hand or power tools, shall be permitted to be made only after all operations have ceased and all sulfur has been removed from the vicinity, protected in tight noncombustible containers, or sufficiently wet with water to prevent ignition.

23.11.4.3 Activities described in 23.11.4.2 shall be controlled by a hot work permit system in accordance with the requirements of *NFPA 51B*.

23.11.5 Firefighting.

23.11.5.1 Protection for covered liquid sulfur storage tanks, pits, and trenches shall be by one of the following means:

- (1) Inert gas system in accordance with *NFPA 69*
- (2)* Steam extinguishing system capable of delivering a minimum of 2.5 lb/min (1.13 kg/min) of steam per 100 ft³ (2.83 m³) of volume
- (3)* Rapid sealing of the enclosure to exclude air

23.11.5.2 Snuffing Steam and Sealing Steam Precautions.

23.11.5.2.1 The vent systems on enclosed sulfur tanks and sulfur pits shall be designed to allow the required snuffing steam rate or sealing steam rate to vent without overpressuring the enclosure.

23.11.5.2.2 The vent systems shall also be designed for proper operation during normal operation.

23.11.5.3 Water Extinguishing Precautions.

23.11.5.3.1 Liquid sulfur stored in open containers shall be permitted to be extinguished with a fine water spray.

23.11.5.3.2 Use of high-pressure hose streams shall be avoided.

23.11.5.3.3 The quantity of water used shall be kept to a minimum.

23.11.5.4 Dry Chemical Extinguishers. Where sulfur is being heated by a combustible heat transfer fluid, dry chemical extinguishers complying with *NFPA 17* shall be provided.

23.12 Handling of Liquid Sulfur and Sulfur Vapor at Temperatures Above 309°F (154°C).

23.12.1 General.

23.12.1.1 Section 23.12 shall apply to liquid sulfur and its vapors when heated in closed containers to temperatures above 309°F (154°C).

23.12.1.2 The requirements of Section 23.11 shall apply.

23.12.2 Operating Precautions and Equipment Design.

23.12.2.1 Equipment shall be designed to be closed as tightly as possible to prevent escape of vapor and to exclude air from the system during operation.

23.12.2.2 Deflagration Venting.

23.12.2.2.1 Process equipment shall be provided with deflagration venting, in accordance with *NFPA 68*.

23.12.2.2.2 Where vent ducts are required, the vent pipes or ducts shall be heated to prevent condensation of sulfur vapor.

23.12.2.3 An adequate supply of a suitable inerting agent such as steam shall be available at all times for blanketing and purging equipment.

23.12.2.4 All buildings or enclosures for such processes shall comply with 9.3.5.2.1, 23.9.3.2.2, 23.9.3.2.3.1, 23.9.3.2.3.2, 23.9.3.2.3.3, and 23.9.3.3.

23.12.2.5 Where sulfur is vaporized and subsequently condensed to sulfur dust, handling of the finely divided sulfur from the process shall comply with the requirements of Sections 23.4 through 23.9.

Chapter 24 Wood Processing and Woodworking Facilities

24.1 Administration.

24.1.1 Scope. This standard provides the minimum requirements for fire and explosion prevention and protection of industrial, commercial, or institutional facilities that process wood or manufacture wood products using wood or other cellulosic fiber as a substitute for or an additive to wood fiber, and facilities that process wood, creating wood chips, particles, or dust.

24.1.1.1 Woodworking and wood processing facilities shall include, but are not limited to, wood flour plants, industrial woodworking plants, furniture plants, plywood plants, composite board plants, lumber mills, production-type woodworking shops, and carpentry shops.

24.1.1.2* For woodworking operations that occupy areas smaller than 5000 ft² (465 m²), and where dust-producing equipment requires an aggregate dust collection flow rate less than 1500 ft³/min (2549 m³/hr), only the requirements contained in the following sections of this standard shall apply:

- (1) Chapters 1 through 3 and Section 24.1 through Section 24.3
- (2) 8.3.3
- (3) Section 8.4 through Section 8.11 and 24.8.4 through 24.8.11
- (4) Section 9.5
- (5) 9.6.13

24.1.2 Purpose. The purpose of this standard shall be to provide minimum requirements, with due function, for the design, operation, and maintenance of woodworking and wood processing facilities for the safety to life, property protection, and mission continuity from fire and explosion.

24.1.2.1 Goal. The goal of this standard shall be to provide for a woodworking and wood processing facility that is reasonably protected from fire or deflagration in a cost-effective manner.

24.1.3 Application. This chapter shall modify and augment the requirements of Chapters 1 through 10.

24.2 Reserved.

24.3 Reserved.

24.4 Reserved.

24.5 Hazard Identification.

24.5.1 Reserved.

24.5.2 Screening for Combustibility or Explosibility. Wood particulates in a facility shall be assessed for their hazards in accordance with Chapter 5.

24.5.2.1 A wood particulate having a moisture content of less than 25 percent (wet basis) and a mass median particle size of less than 500 micron shall be deemed to be a deflagrable wood dust unless testing shows it not to be capable of propagating deflagration.

24.5.2.2 A wood particulate having a moisture content of less than 25 percent, wet basis, and having a mass median particle size greater than 0.2 in. (5.0 mm) (3.5 mesh sieve) shall be permitted to be considered nondeflagrable wood dust on the basis of particle size.

24.5.2.3* The assessment of hazard on the basis of mass median particle size shall be limited to those locations in the process and facility where the wood particulate remains a uniform mixture.

24.5.2.4* When the testing laboratory reports that a sample cannot be tested in accordance with ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, or an equivalent protocol, based on particle size only, it shall be permitted to consider the particulate to be nondeflagrable.

24.6 Reserved.

24.7* Process and Dust Hazards Analysis.

24.7.1 General Requirements.

24.7.1.1 The design of the fire and deflagration safety provisions of the facility shall be based upon an analysis of the facility, the process, and the fire or deflagration hazards encompassed by the facility and process.

24.7.1.2 The design of systems and facilities that handle combustible particulate solids shall address the physical and chemical properties and hazardous characteristics of the materials in the hazard area.

24.7.1.3 The results of the facility and process analysis shall be permanently documented.

24.7.1.4 The facility and process analysis shall be reviewed and the documented results revised when the process is changed in accordance with the management-of-change criteria in Section 8.11 and 24.8.11.

24.7.1.5 The results of the process analysis shall be maintained for the life of the facility and process.

24.7.1.6 The process analysis shall include a dust hazards analysis performed in accordance with Chapter 7.

24.7.2 Reserved.

24.7.3 Methodology.

24.7.3.1 Reserved.

24.7.3.2 Reserved.

24.7.3.3 Reserved.

24.7.3.4 Building or Building Compartments.

24.7.3.4.1* A deflagration hazard shall be deemed to exist in a building compartment when the layer of accumulated fugitive deflagrable wood dust averaged over all upward-facing surfaces in the building compartment exceeds 1/8 in. (3.2 mm) in thickness.

24.7.3.4.2 A deflagration hazard shall be determined to exist unless otherwise determined by a dust hazards analysis, as described in Chapter 7.

24.7.3.4.3* The layer thickness criterion in 24.7.3.4.1 shall be permitted to be corrected for dusts having a settled bulk density other than 20 lb/ft³ (320 kg/m³) using the following formula:

For US customary units:

$$T = \frac{(0.125 \text{ in.})(20 \text{ lb/ft}^3)}{(\text{Settled Bulk Density, lb/ft}^3)} \quad [24.7.3.4.3a]$$

where:

T = The allowable thickness (in.)

For SI units:

$$T = \frac{(3.2 \text{ mm})(320 \text{ kg/m}^3)}{(\text{Settled Bulk Density, kg/m}^3)} \quad [24.7.3.4.3b]$$

where:

T = The allowable thickness (mm)

24.8 Management Systems.

24.8.1 Reserved.

24.8.2 Reserved.

24.8.3 Reserved.

24.8.4 Housekeeping.

24.8.4.1 General.

24.8.4.1.1* This section shall apply to the monitoring and removal of combustible waste materials in order to prevent these materials from accumulating outside, on, or around operating equipment or otherwise within the facility in sufficient quantity to create an undue fire hazard.

24.8.4.1.2* Any waste material or debris found in large enough quantity that the material is heavily coated or is in any way impeding the operation of energized or moving equipment shall be collected and removed immediately.

24.8.4.1.3 Combustible waste that cannot be reintroduced to the production process or utilized as fuel shall be placed in covered metal receptacles until removed to a safe place for daily disposal.

24.8.4.1.4 Any metal collected through the cleanup process shall be separated from wood debris or combustible waste to prevent entry into the wood-handling or processing equipment, the dust-collecting system, or the scrap wood hog.

24.8.4.1.5* Production equipment shall be maintained and operated in a manner that minimizes the escape of debris or dust in accordance with Chapter 9.

24.8.4.1.6* Ignitable (flammable and combustible) liquid spills or leaks from any source shall be cleaned up without delay.

24.8.4.1.7 Residue from condensation of oil and resin volatiles shall be removed from areas within, around, and over curing ovens, dryers, fume extraction systems, or ventilation systems.

24.8.4.1.8 Oil-soaked cloths or waste material shall be stored in approved metal receptacles with self-closing covers.

24.8.4.1.9 Oily clothing, if stored between shifts, shall be kept in metal lockers.

24.8.4.1.10 Ignitable (flammable and combustible) liquids shall be handled and stored in accordance with NFPA 30.

24.8.4.2 Methodology. Surfaces shall be cleaned in a manner that minimizes the generation of dust clouds.

24.8.4.2.1* Procedure. (Reserved)

24.8.4.2.2 Vacuum Cleaning Method.

24.8.4.2.2.1 Portable Vacuum Cleaners. When used in Class II areas, as determined in accordance with 24.9.6.14.2, portable electrical vacuum cleaning equipment in accordance with 8.4.2.2.1 shall meet one of the following:

- (1) Listed for use in Class II hazardous locations
- (2) Unlisted and the powered suction source located in a remote, unclassified area

24.8.4.2.3 Sweeping, Shoveling, Scoop, and Brush Cleaning Method. Vigorous sweeping that produces a dust suspension shall be permitted only if the following conditions are met:

- (1) Prior to vigorous sweeping, vacuum cleaning, gentle sweeping, or water washdown methods are used to clean surfaces that can be safely accessed.
- (2) Dust accumulations in the area after vacuum cleaning, gentle sweeping, or water washdown do not exceed the threshold housekeeping dust accumulation.
- (3) All electrical equipment, including lighting, potentially exposed to airborne dust in the area during cleaning is rated appropriately for dust in accordance with NFPA 70.
- (4) All ignition sources and hot surfaces capable of igniting a dust cloud or dust layer are shut down or removed from the area.
- (5) After sweeping elevated surfaces is complete, residual dust on lower surfaces is cleaned prior to re-introduction of potential ignition sources.
- (6) All fire protection equipment is in service.

24.8.4.2.4 Reserved.

24.8.4.2.5 Reserved.

24.8.4.2.6* Compressed Air Blowdown Method.

24.8.4.2.6.1* A documented risk assessment shall be permitted to be used to determine which precautions in 8.4.2.6.2 are required for the specific conditions under which compressed air is being used.

24.8.5 Reserved.

24.8.6 Reserved.

24.8.7 Inspection, Testing, and Maintenance.

24.8.7.1 An inspection, testing, and maintenance program shall be developed to ensure that fire and explosion protection systems are in accordance with Chapter 9 and Section 24.9.

24.8.7.2 The inspection, testing, and maintenance program shall be a documented program detailing the equipment inspected, testing performed, test results formulated, and maintenance or repair requirements.

24.8.7.3* Process controls, equipment, and machinery shall be inspected, tested, and maintained in accordance with the manufacturer's recommended guidelines and safe practices.

24.8.7.4 Dust Collection Systems.

24.8.7.4.1* The entire system, including each fan, motor, blower unit, operating control panels, fume scrubbers, flexible connections, and dampers, shall be inspected and maintained in accordance with the manufacturer's recommended guidelines and safe practices.

24.8.7.4.2* Aluminum paint shall not be used on interior steel surfaces.

24.8.7.4.3 Filters shall be cleaned or replaced when their resistance to airflow exceeds the manufacturer's specifications.

24.8.7.4.4 Filter media shall not be replaced with an alternative type unless a thorough evaluation of the fire hazards has been performed, documented, and reviewed by management.

24.8.7.4.5 Where ducts are protected with sprinklers, sprinklers covered with deposits or corrosion shall be replaced or sent to a recognized testing lab for evaluation of suitability for continued service.

24.8.7.4.6 All vents for the relief of pressure caused by deflagrations shall be maintained free and clear of all obstructions and pursuant to the manufacturer's recommendations.

24.8.7.4.7 Maintenance shall not be performed on fans, blowers, or other equipment while the unit(s) is operating.

24.8.7.5 Impairments of Fire Protection and Explosion Prevention Systems.

24.8.7.5.1* Impairments shall include anything that interrupts the normal intended operation of the fire protection or explosion prevention system.

24.8.7.5.2* A written impairment procedure shall be followed for every impairment to the fire protection or explosion prevention system.

24.8.7.5.3* Impairments shall be limited in size and scope to the system or portion thereof being repaired, maintained, or modified.

24.8.7.5.4* Impairment notification procedures shall be implemented by management to notify plant personnel and the authority having jurisdiction of existing impairments and their restoration.

24.8.8 Training and Hazard Awareness.

24.8.8.1 The training and hazard awareness requirements in Section 8.8 shall also apply to noncombustible-dust hazards covered by this chapter.

24.8.8.2 General safety training shall ensure that all employees are knowledgeable about the following:

- (1) General plant safety rules
- (2) Emergency procedures
- (3) Procedure for reporting an accident or unsafe conditions
- (4) Housekeeping policy and practices
- (5) Basic personal protective equipment requirements
- (6) Location of safety office, medical center, and first-aid stations
- (7) Emergency routes, exits, and safe shelters
- (8) Location of fire protection equipment
- (9) Hazardous areas

24.8.8.3 Job-specific training shall ensure that all employees are knowledgeable about the following:

- (1)* The hazards of their working environment and their behavior and procedures in case of emergencies, including fires, explosions, and hazardous materials releases
- (2) Emergency response plans, including safe and proper evacuation of their work area and the permissible methods for fighting incipient fires in their work area
- (3) The necessity for proper functioning of related fire and explosion protection systems that are under their responsibility
- (4) Equipment maintenance requirements and practices, including lockout/tagout procedures
- (5) Safe handling, use, storage, and disposal of hazardous materials used in the employees' work areas
- (6) The location and operation of fire protection equipment, manual pull stations and alarms, emergency phones, first-aid supplies, and safety equipment
- (7) Equipment operation, safe startup and shutdown, and response to upset conditions
- (8) The decision-making process necessary to determine the degree and extent of the hazard and the personal protective equipment and job planning necessary to perform the task safely

24.8.8.4* A qualified person shall be trained and knowledgeable of the construction and operation of equipment or a specific work method, and shall be trained to recognize and avoid potential hazards present with respect to that equipment or work method.

24.8.8.5 Training programs and procedures shall be reviewed and updated at least annually and whenever workplace conditions (i.e., equipment, process, chemical, material storage) change.

24.8.8.6* Emergency awareness training shall be given to all employees when emergency plans are initially implemented, revised, or updated and at least annually.

24.8.9 Reserved.

24.8.10* Incident Investigation.

24.8.11* Management of Change. The requirements in 24.8.11 shall apply in addition to Section 8.11.

24.8.11.1 Management shall implement and maintain a system to evaluate proposed changes to the facility and processes, both physical and human, for the impact on safety, loss prevention, and control.

24.8.11.2* Management of change shall include review of all projects involving the following:

- (1)* Occupancy and process changes involving storage configurations and heights, process equipment and materials, or rates of production
- (2)* Changes to all fire protection and alarm systems
- (3)* Exposure changes
- (4) Human element changes involving key members of loss prevention programs
- (5) New construction or modification to an existing structure

24.8.12 Reserved.**24.8.13 Documentation Retention.**

24.8.13.1* Records requiring retention shall include, but are not limited to, drawings and supporting documents relating to initial installation/purchase of equipment, routine equipment inspections, testing and repair history, fire and safety inspection or audit reports, service records, and manufacturer's data sheets.

24.8.13.2* Records of inspections, tests, and maintenance of fire protection equipment and components shall be retained and made available to the authority having jurisdiction upon request.

24.8.13.3* All records required to be kept shall be retained until their usefulness has been served or until no longer required by the applicable standard or authority having jurisdiction.

24.8.13.4* Records shall be maintained on-site by the owner.

24.8.13.5* Retained records shall indicate the procedure performed (e.g., installation, inspection, testing, training, or maintenance), the organization that performed the work, the results, and the date the work was performed.

24.9 Hazard Management: Mitigation and Prevention.**24.9.1 Reserved.****24.9.2 Reserved.****24.9.3 Building Design.****24.9.3.1* Construction.****24.9.3.2 Building or Building Compartment Protection.**

24.9.3.2.1* Compartmentation. Where required by other sections of this standard, passive fire protection features shall be utilized to prevent the spread of fires or deflagrations to adjacent compartments or occupancies. Passive fire protection features shall include, but not be limited to, space separation, fire walls, fire partitions, or draft curtains.

24.9.3.2.2 Fire Resistance Rating. When applying 9.3.5.2.2, where no building code exists, fire barrier walls shall have a minimum fire resistance rating of 1 hour.

24.9.3.2.3 Protection of Openings and Penetrations.

24.9.3.2.3.1 Penetrations of walls, floors, or ceilings that provide a required fire separation shall be protected by listed systems or approved materials that have a fire resistance rating equal to that of the wall, floor, or ceiling and shall conform to the relevant requirements of NFPA 221.

24.9.3.2.3.2 Penetrations in barriers erected to segregate dust hazards shall be dusttight.

24.9.3.2.3.3* Conveyor and chute openings in fire walls shall be protected by listed or approved, automatic-closing fire doors or fire dampers that have a fire resistance rating equivalent to the fire wall.

24.9.3.2.3.4 Fire doors shall be designed, installed, tested, and maintained in accordance with NFPA 80.

24.9.3.2.3.5 Openings in walls designed to be explosion resistant shall be protected by doors that provide the same degree of explosion resistance protection as the walls.

(A) Such doors shall be kept closed at all times when not actually being used.

(B)* Such doors shall not be considered as part of a required means of egress to satisfy the requirements of NFPA 101.

24.9.3.3 Life Safety.

24.9.3.3.1 Occupant life safety systems shall be designed, constructed, installed, and maintained in accordance with NFPA 101.

24.9.3.3.2 The means of egress shall comply with NFPA 101.

24.9.3.3.2.1* Means of egress for building or building compartments that contain a deflagration hazard area shall be designed according to Section 7.11 in NFPA 101.

24.9.3.3.3 The design and construction of the building, mechanical and electrical systems, and systems and equipment necessary to the wood utilization occupancy shall be such that the occupants are able to recognize hazards and egress safely from the building in the event of one of the anticipated hazards.

24.9.3.3.4 The building design shall be such that the means of egress is clearly identifiable and usable for occupancy.

24.9.3.4* Construction Features to Limit Accumulation. (Reserved)**24.9.3.5 Reserved.****24.9.3.6* Damage-Limiting Construction.**

24.9.3.6.1 Dust deflagration hazard areas shall be separated or segregated from all other areas.

24.9.3.6.2* Where a deflagration hazard is known to exist in a room or building, exterior walls shall be designed, constructed, and maintained such that they relieve the pressure from a dust deflagration without damage to the load-bearing capacity of the structure.

24.9.3.6.3* Interior walls erected to isolate dust explosion hazards shall be designed for sufficient explosion resistance to preclude damage to these walls before the explosion pressure can be safely vented to the outside.

24.9.3.7 Draft Curtains.

24.9.3.7.1 Where required, draft curtains shall be constructed and installed in accordance with Chapter 7 in NFPA 204.

24.9.3.7.1.1 Minimum 26 gauge steel sheeting [0.018 in. (0.455 mm)] shall be used.

24.9.3.7.1.2 Where automatic sprinkler protection is provided, draft curtains shall be permitted to be constructed of wood panels ½ in. (12.7 mm) thick or greater.

24.9.3.7.1.3 Aluminum sheeting, fiberglass reinforced plastic (FRP), or other plastic materials shall not be used.

24.9.3.7.2 Solid beams, purlins, and other solid structural members extending down from the roof deck or ceiling shall be deemed equivalent to draft curtains if the depth criteria in Chapter 7 of NFPA 204 is met.

24.9.4 Equipment Design.

24.9.4.1 General.

24.9.4.1.1* Applicability. Subsection 24.9.4 shall apply to storage, all pneumatic systems, dust control systems, mechanical conveyors, and mechanical equipment of all types used to convey, resize, pulverize, dry, or otherwise process wood and wood-derived particulate and other cellulosic materials used as a substitute or supplement for wood.

24.9.4.1.2 Fire Protection and Explosion Suppression Systems.

Where required, fire protection and explosion suppression systems shall be provided in accordance with Sections 9.8, 9.9, 24.9.8, and 24.9.9.

24.9.4.2 Reserved.

24.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

24.9.4.3.1* General Requirements. The hazard associated with the particulate conveying system shall be determined through a hazards analysis.

24.9.4.3.1.1 The analysis of the fire and deflagration hazard shall address the moisture content and particle size distribution of the particulate at each point of material entry into the duct system to determine whether the material is green, dry nondeflagrable, or deflagrable.

24.9.4.3.1.2 The analysis of the fire and deflagration hazard shall identify the minimum explosible concentration (MEC) for all deflagrable material.

24.9.4.3.1.3 Fire and deflagration hazards shall be permitted to be deemed nonexistent where only green material is collected or conveyed and construction of the equipment handling and storing the material is all noncombustible.

24.9.4.3.1.4* A fire hazard shall be deemed to exist in the system wherever dry wood particulate is collected or conveyed or wherever components of the conveying system are constructed of combustible materials.

24.9.4.3.1.5* In addition to the fire hazard, a deflagration hazard shall also be deemed to exist where deflagrable wood dust is, or could be, suspended in air during operation at a maximum concentration above 25 percent of the MEC.

24.9.4.3.2 Specific Requirements for Pneumatic Conveying Systems.

24.9.4.3.2.1 General Requirements.

(A) Pneumatic conveying systems shall be designed in accordance with Chapter 9 except as modified by this chapter.

(B)* Woodworking pneumatic conveying systems shall be restricted to handling wood residues; under no circumstances shall another operation that generates sparks, such as from grinding wheels, or flammable vapors, such as from a finishing operation, be connected to a woodworking pneumatic conveying system.

(C) Once a system airflow has been properly balanced, additional pickup points, duct modifications, and modification of balancing damper settings shall not be made without ensuring that the remaining portions of the system still have sufficient capture and conveying air velocities for their intended function.

(D)* Every section of the collection system shall be sized for not less than the minimum air velocity and volume required to collect and transport the material through the ducting and into the collection equipment.

24.9.4.3.2.2 Duct System.

(A) Ductwork shall be metallic.

(B) Flexible ducting shall be permitted for final machine connection in a length not exceeding the minimum required for machine operation.

(C)* Nonconductive ducts such as PVC pipes shall not be permitted.

(D) Where extinguishing is present, horizontal ductwork subject to water accumulation shall be capable of supporting the weight of the duct system plus the weight of the duct half-filled with water.

(E) Ductwork shall be protected from corrosion.

(F) Dust collection air velocity and volume shall be calculated according to 24.9.4.3.2.2(G) and 24.9.4.3.2.2(H).

(G) The capacity of the system shall be calculated on the basis of all hoods and other openings connected to the system being open or equipped with means to ensure minimum conveying velocity of 24.9.4.3.2.1(D) in all sections of the system.

(H) Floor sweeps, which are normally closed and are only opened on an occasional basis to facilitate housekeeping, shall be permitted to be excluded from the air flow calculations for the system.

(I)* Where dampers or gates are used for individual equipment, the volume and velocity resulting from the operation of such dampers or gates shall not reduce the system velocity below the design minimum.

(J) Ducts used to convey particulate shall have a circular cross-section unless a non-circular cross-section of equal area is needed where the duct connects to other equipment or where external obstructions necessitate a non-circular cross-section be used.

(K) Ductwork shall be bonded and grounded in accordance with 24.9.6.6.1(1).

(L)* **Hazards Determination.** The dust accumulation hazard associated with the duct system shall be determined by means of a hazards analysis.

(M)* **Duct Access** For duct systems subject to dust accumulation, access doors, openings, or removable sections of ductwork shall be provided in accordance with 24.9.4.3.2.2(L)

24.9.4.3.2.3 Hoods and Enclosures.

(A) Hoods or enclosures shall be designed and located such that the wood dust or particulate generated will fall, be projected, or be drawn into the hoods or enclosures so as to minimize fugitive dust emissions without interfering with the safe and satisfactory operation of the machine.

(B) **Reserved.**

(C) **Reserved.**

(D) All hoods and enclosures shall be of noncombustible construction unless protected with automatic sprinklers installed in accordance with NFPA 13.

24.9.4.3.2.4 Fans and Blowers (Air-Moving Devices).

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

(B) Fans and blowers shall be permitted to be located in accordance with 24.9.4.3.2.4(B)(1) through 24.9.4.3.2.4(B)(6):

- (1)* On the clean air side of dust collectors, regardless of the moisture content or particle size of the material being conveyed
- (2)* Upstream of the dust collector when the material being conveyed has a moisture content in excess of 25 percent (wet basis)
- (3) Upstream of the dust collector when the material being conveyed has a moisture content of less than 25 percent (wet basis) and the concentration of sub-500 micron particulate is less than 25 percent of the MEC, and the duct downstream of the fan is equipped with a listed spark detection extinguishing system and/or abort system
- (4) Upstream of the dust collector when the material being conveyed has a moisture content of less than 25 percent (wet basis) and the concentration of sub-500 micron particulate is in excess of 25 percent of the MEC, and the duct and dust collector are equipped with either deflagration relief venting or deflagration suppression systems
- (5) Upstream of enclosureless dust collectors, in accordance with 24.9.4.4
- (6) Upstream of outdoor cyclone collectors receiving knife planer shavings when the fan and the cyclone are located outdoors and exhaust to outdoor atmosphere

(C)* When fans with a deflagration hazard are arranged as material-handling fans on ducts, the fan housing shall meet the same design strength criteria required of the duct in 9.5.1.1.

24.9.4.3.3 Specific Requirements for Dust Collection Systems. The requirements in 24.9.4.3.2 shall apply to dust collection systems.

24.9.4.4 AMS. The system shall be provided with an AMS of sufficient size and capacity to maintain the required airflow and efficiently separate the material from the air before the air is exhausted.

24.9.4.4.1 Reserved.

24.9.4.4.2 Reserved.

24.9.4.4.3 Reserved.

24.9.4.4.4* Enclosureless AMS. The requirements in 24.9.4.4 allowing the use of enclosureless AMS shall be limited to enclosureless AMS that meet all of the following criteria:

- (1) The filtration is accomplished by passing dust-laden air through filter media, collecting the dust on the inside of the filter media, and allowing cleaned air to exit to the surrounding area.
- (2) The filter media are not enclosed or in a container.
- (3) There is no means to mechanically shake or pressure-pulse the filter media while the fan is on.
- (4) The filter media are under positive pressure.
- (5) Removal of the collected dust is not automatic, continuous, or mechanical.

24.9.4.4.5* AMS Locations. Dust collectors shall be located in accordance with one of the following:

- (1) Outside of buildings
- (2) Indoors when deemed to have no fire or deflagration hazard
- (3) Indoors for dust collectors with only a fire hazard when protected in accordance with this standard
- (4) Indoors when equipped with listed deflagration suppression system
- (5) Indoors when equipped with deflagration relief vents with relief pipes extending to safe areas outside the building and the collector meets the strength requirement of this standard
- (6) Indoors when equipped with deflagration relief vents exhausting through listed flame-quenching devices and the collector meets the strength requirement of this standard
- (7)* Indoors for enclosureless dust collectors meeting all of the following criteria:
 - (a) The collector is used only for dust pickup from wood processing machinery (i.e., no metal grinders and so forth).
 - (b) The collector is not used on sanders, molders, or abrasive planers having mechanical material feeds through the machine.
 - (c) Each collector has a maximum air-handling capacity of 5000 cfm (2.36 m³/sec).
 - (d) The fan motor is of a totally enclosed, fan-cooled design.
 - (e) The collected dust is removed daily or more frequently if necessary to ensure efficient operation.
 - (f) The collector is located at least 20 ft (6.1 m) from any means of egress or area routinely occupied by personnel.
 - (g) Multiple collectors in the same room are separated from each other by at least 20 ft (6.1 m).

24.9.4.4.6 AMS Clean Air Exhaust.

24.9.4.4.6.1* In addition to 9.4.4.6.3, recycling of AMS exhaust to buildings shall be permitted if combustible particulate solids in the recycled air are not in concentrations above applicable industrial hygiene limits, and the provisions of 24.9.4.4.6.2 are met.

24.9.4.4.6.2* Air from air-material separators or dust collectors deemed to have a fire hazard shall meet the provisions of 24.9.4.4.6.2(A), 24.9.4.4.6.2(B), 24.9.4.4.6.2(C), or 24.9.4.4.6.2(D).

(A)* For dust collection systems of capacity less than or equal to 5000 cfm (2.36 m³/sec), one of the following shall apply:

- (1) The system shall be equipped with listed spark detection, designed and installed in conformance with the relevant sections of NFPA 72 located on the duct upstream from the dust collector and downstream from the last material entry point, connected directly to a listed spark extinguishing system, designed and installed in conformance with NFPA 15 or
- (2) The system shall be protected in accordance with 24.9.4.4.6.2(B).

(B)* For dust collection systems of capacity greater than 5000 cfm (2.36 m³/sec), the following shall apply:

- (1) The system shall be equipped with a listed spark detection system, designed and installed in conformance with the relevant sections of *NFPA 72* located on the duct upstream from the dust collector and downstream from the last material entry point, or on the exhaust side of the dust collector, to detect fire entering or occurring within the dust collector, respectively, and
- (2) The exhaust air duct conveying the recycled air back to the building shall be equipped with a high-speed abort gate activated by the spark detector in 24.9.4.4.6.2(B)(1), and the abort gate shall be sufficiently fast to intercept and divert any burning material to atmosphere before it can enter the plant.
- (3)* The abort gate is provided with a manual reset so that, after it has aborted, it can be reset to the normal position only by manual interaction at the damper; automatic or remote reset shall not be allowed. A powered reset is acceptable if it can be activated only by manual interaction at the damper location.

(C) Air from enclosureless dust collectors meeting the requirements of 24.9.4.4.5(7) shall be permitted to be exhausted into the building.

(D) Air from cyclone pre-cleaners, located outside the building and having a capacity of 5000 cfm (2.36 m³/sec) or less shall be permitted to be ducted directly to enclosureless dust collectors located within the building.

24.9.4.4.7 AMS Construction.

24.9.4.4.7.1* Dust collectors shall have independent supporting structures capable of supporting the weight of the following:

- (1) Collector
- (2) Material being collected
- (3) Any water from fire-extinguishing systems that will not readily drain from the system

24.9.4.5 Reserved.

24.9.4.6 Reserved.

24.9.4.7 Reserved.

24.9.4.8 Reserved.

24.9.4.9 Reserved.

24.9.4.10* Size Reduction.

24.9.4.10.1* Unless the particulate size reduction equipment is strictly dedicated to handling green material or is pressurized with steam, it shall be considered a high-frequency ignition source.

24.9.4.10.2 The fire and deflagration potential of each piece of particulate size reduction machinery shall be determined by a hazards analysis.

24.9.4.10.3* All equipment shall be designed in accordance with 24.9.4.15.

24.9.4.10.4* Exclusion or removal of foreign material shall comply with 9.4.10.

24.9.4.10.5 Size reduction equipment with a deflagration hazard shall comply with 24.9.8.2.5.

24.9.4.10.6 Size reduction equipment with a fire hazard shall comply with 24.9.9.8.5.

24.9.4.11 Reserved.

24.9.4.12 Reserved.

24.9.4.13 Mechanical Feeding Devices.

24.9.4.13.1* When failure of a mechanical feeding device could cause significant combustible dust hazards, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

24.9.4.13.2 Controls shall be provided to monitor the operation status of the equipment.

24.9.4.14* Bucket Elevators.

24.9.4.14.1 Casing, head and boot sections, access openings, and connecting spouts shall be as dusttight as practicable and shall be constructed of noncombustible materials.

24.9.4.14.2* Inspection openings shall be provided in the boot section to allow clean-out of the boot and inspection of the alignment of the boot pulley and belt.

24.9.4.14.3 Inspection openings shall be provided in the head section to allow complete inspection of the head pulley lagging, the belt and pulley alignment, and the discharge throat of the leg.

24.9.4.14.4* Each leg shall be independently driven by motor(s) and drive train(s) capable of handling the full-rated capacity of the elevator leg without overloading.

24.9.4.14.4.1 Multiple motor drives shall be interlocked to prevent operation of the leg upon failure of any single motor.

24.9.4.14.4.2 The drive shall be capable of starting the unchoked leg under full (100 percent) load.

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

24.9.4.14.6 The use of plastic, rubber, and other combustible linings shall be limited to high-impact areas and wear surfaces.

24.9.4.14.7 The leg head section between the up and down casings shall be sloped at an angle of not less than 45 degrees.

24.9.4.14.8 All spouts shall be designed and installed to handle the full-rated elevating capacity of the largest leg feeding such spouts.

24.9.4.14.9 Legs shall have lagging installed on the head pulley to minimize slippage.

24.9.4.14.10 Leg conveyor belts and lagging shall have a surface electrical resistivity not greater than 300 megaohms per square (3×10^8 ohms per square). (See A.21.9.4.15.5.)

24.9.4.14.11 Leg belts and lagging shall be fire resistant and oil resistant.

24.9.4.14.11.1 Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 18.65, or the flame test for belting in Part 13.2 of

ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*.

24.9.4.14.12* Monitors.

24.9.4.14.12.1 Where determined necessary by the DHA, monitors shall be provided at head, tail, and knee pulley bearings that indicate high bearing temperature or vibration detection.

24.9.4.14.12.2 Where determined necessary by the DHA, monitors shall be provided for head, tail, and knee pulley alignment and belt alignment.

24.9.4.14.12.3 Abnormal conditions shall actuate a visual or an audible and visual alarm requiring corrective action.

24.9.4.14.13 Explosion Prevention/Protection. Where an explosion hazard exists, protection of bucket elevator legs shall be in accordance with Section 9.8 and 24.9.8.

24.9.4.15 Conveyors and Spouts.

24.9.4.15.1 All equipment shall be designed, installed, and operated to maintain alignment and lubrication to avoid excessive heat buildup from friction, hot bearings, and so forth.

24.9.4.15.2* All equipment shall be designed to minimize fugitive dust emissions from the equipment.

24.9.4.15.3 Dusttight ball or roller bearings shall be used wherever practicable.

24.9.4.15.4 All bearings and bushings shall be dusttight.

24.9.4.15.5* Bearings and bushings shall be located outside the equipment unless equipment design makes it impractical.

24.9.4.15.6 Shaft seals shall be provided where rotating shafts penetrate equipment walls.

24.9.4.15.7* Access hatches and removable equipment covers shall be tight fitting and securely fastened for dusttight operation.

24.9.4.16 Mixers and Blenders.

24.9.4.16.1 Mixers and blenders shall be designed to control fugitive dust emissions.

24.9.4.16.2* Foreign materials that can become ignition sources shall be prevented from entering the mixer or blender.

24.9.4.16.3 Clearance and alignment of moving parts in equipment 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.

24.9.4.16.4 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.

24.9.4.16.5 Where an explosion hazard exists as described in Chapter 7, protection shall be in accordance with Section 9.5.

24.9.4.16.6 Where a fire hazard exists, protection shall be in accordance with Section 9.9.

24.9.4.17 Dryers.

24.9.4.17.1 Reserved.

24.9.4.17.2* Veneer and Fiberboard Dryers.

24.9.4.17.2.1* Automatic water spray deluge protection shall be provided for horizontal tray dryers, air plenums, and air exhaust stacks.

(A) Protection shall not be required for the following:

- (1) Portions of the dryer where the material has a moisture content greater than 40 percent (wet basis), there are no thermal oil heat exchangers in the dryer, and combustible debris or deposits do not accumulate inside the dryer.
- (2) Portions of the dryer that have two or fewer trays, there are no thermal oil heat exchangers in the dryer, and combustible debris or deposits do not accumulate inside the dryer.

24.9.4.17.2.2 Where two or more deluge systems are provided in the same dryer, the water demand shall be designed for two systems operating at one time. (See Annex X.)

24.9.4.17.2.3* The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep dust and resin deposits to less than $\frac{1}{8}$ in. (3.2 mm) thick.

24.9.4.17.2.4* The ceiling areas above these dryers shall receive regular cleaning, especially around roof exhaust fan openings, to keep dust and resin deposits to less than $\frac{1}{8}$ in. (3.2 mm) thick.

24.9.4.17.2.5 Ceiling areas above veneer and fiberboard dryers shall have draft curtains to contain dust and resin deposits locally to each dryer.

24.9.4.17.2.6 Where automatic sprinkler protection is provided within the draft curtained area, the sprinkler design operating area shall be based on all heads flowing within the curtained area if this area is greater than the normal design area.

24.9.4.17.3* Rotary Dryers.

24.9.4.17.3.1 Rotary dryers having a deflagration hazard shall be located in one of the following places:

- (1) Outdoors
- (2) In a separate detached building
- (3) In a separate cutoff room with damage-limiting construction

24.9.4.17.3.2* Rotary dryers shall have automatic spark detection and extinguishing systems installed between the dryer drum and downstream material-handling equipment, such as cyclones or wind boxes.

24.9.4.17.3.3* The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep combustible deposits to a minimum.

24.9.4.17.4* Conveyor Dryers.

24.9.4.17.4.1* Conveyor dryers shall be protected with water spray deluge systems, activated by spark, flame, and/or heat detectors.

24.9.4.17.4.2 Dust collection systems used to capture dust emissions in or between individual conveyor dryers shall be designed in accordance with 24.9.4.3.2.

24.9.4.17.4.3* The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep dust and resin deposits to a minimum.

24.9.4.17.5* Flash Tube Dryers.

24.9.4.17.5.1 The location of the flash dryers shall comply with one of the following:

- (1) Flash dryers shall be located outdoors.
- (2) Flash dryers shall be located in a building physically detached from the main production building.
- (3) Flash dryers shall be permitted to be installed such that the head-end portion of a flash dryer, in which the moisture content of the material being dried is greater than 40 percent (dry basis), is located inside the main production building.
- (4) Flash dryers shall be permitted to be installed such that any portion of a flash dryer, in which the moisture content of the material being dried is less than 40 percent (dry basis), is located inside the main production building if it has explosion protection designed in accordance with NFPA 69.

24.9.4.17.5.2* Flash tube dryers shall be protected by a combination of spark detection and extinguishing systems, water spray deluge, deflagration relief venting, and process isolation devices and interlocks.

24.9.4.17.5.3* The dryer duct shall be regularly inspected and cleaned to minimize fiber accumulations.

24.9.4.17.6* Kiln Dryers.

24.9.4.17.6.1* Automatic sprinkler protection shall be provided within dry kilns and ovens with a rating over 150,000 Btu/hr.

24.9.4.17.6.2 Sprinklers below the fan decks of dry kilns shall be based on the storage height of product within the kiln, with the operating area being the entire area.

24.9.4.17.6.3 Sprinklers above the fan decks of dry kilns shall be designed to provide 0.15 gpm/ft² (6.1 L/min/m²) density over the entire area.

24.9.4.17.6.4 If the dry kiln is heated by a thermal oil system with hot oil piping inside the kiln that is not all welded (e.g., bolted connections), the minimum sprinkler design density shall be per the requirements in NFPA 13 for Extra Hazard Group 1 occupancies over the entire kiln area.

24.9.4.17.6.5 Hydraulic calculations shall be balanced for the simultaneous operation of all sprinklers above and below the fan deck.

24.9.4.17.6.6* The interior of the dryer shall be regularly inspected and cleaned, if necessary, to keep dust and resin deposits to a minimum.

24.9.4.17.6.7 Fuel burner combustion controls and interlocks shall conform to Section 24.11.

24.9.4.17.7 Finishing Room Dryers. Sprinkler protection provided in finishing room dryers (flammable and combustible solvents) shall be protected as an Extra Hazard Group 2 occupancy as outlined in NFPA 13.

24.9.4.18 Reserved.

24.9.4.19 Hot Presses.

24.9.4.19.1 Continuous Presses.

24.9.4.19.1.1* Continuous presses shall be protected in a manner acceptable to the authority having jurisdiction.

24.9.4.19.1.2 Pits beneath continuous presses shall be protected in accordance with 24.9.4.19.2.

24.9.4.19.2 Multiopening Batch-Type Presses.

24.9.4.19.2.1 For press pit installations that do not utilize thermal oil heating, automatic sprinkler protection shall be provided with a minimum density of 0.20 gpm/ft² (8.15 L/min/m²) over the entire pit area, with a hose stream allowance of 500 gpm (1893 L/min) included in the hydraulic calculations.

24.9.4.19.2.2* For press pit installations where thermal oil heating is used, automatic sprinkler protection shall be designed to provide a minimum density of 0.25 gpm/ft² (10.2 L/min/m²) over the entire pit area, with a hose stream allowance of 500 gpm (1893 L/min) included in the hydraulic calculations.

24.9.4.19.2.3 Where presses are supported on steel columns and thermal oil heating is used, automatic sprinkler protection for steel support columns shall be provided unless the columns are protected with a 2-hour fire-rated material.

24.9.4.20 Reserved.

24.9.4.21 Spray Finishing. Spray finishing operations shall be in accordance with NFPA 33.

24.9.4.22 Dipping and Coating. Dipping and coating operations shall be in accordance with NFPA 34.

24.9.4.23* Air Pollution Control System.

24.9.4.23.1 The air pollution control system shall be designed and maintained in accordance with NFPA 91.

24.9.4.24 Panel Product Manufacturing Machinery.

24.9.4.24.1 Panel formers utilizing dry wood or other cellulosic materials, consisting of particles or fiber of various sizes, shall be provided with dust control to minimize dust clouds within the enclosure.

24.9.4.24.2 Bearings, rollers, and bushings shall be in accordance with 24.9.4.15.1.

24.9.4.24.3 Foreign material shall be removed from the process material feed into all particulate size reduction equipment by permanent magnet or self-cleaning electromagnet-type magnetic separators, or by pneumatic separators, or by both.

24.9.4.24.4 All dust-producing equipment shall be designed for dusttight operation, or the equipment and dust-producing operations shall be provided with dusttight hoods or enclosures that comply with the requirements of 24.9.4.3.

24.9.5 Reserved.**24.9.6 Ignition Source Control.****24.9.6.1 Reserved.****24.9.6.2 Reserved.****24.9.6.3 Hot Surfaces.**

24.9.6.3.1* Bearings shall be dusttight ball or roller type and shall be monitored for adequate lubrication and excessive wear in accordance with 24.9.4.15.1.

24.9.6.4 Reserved.**24.9.6.5 Reserved.****24.9.6.6* Electrostatic Discharges.**

24.9.6.6.1 Conductive Equipment Where equipment is subject to the accumulation of static electric charge, the accumulation of static electric charge shall be controlled by one of the following:

- (1) Permanent grounding and bonding of production equipment
- (2) Grounded metal combs to provide discharge paths
- (3) Other means shown to be effective and acceptable to the authority having jurisdiction

24.9.6.6.2 Maximum Particulate Transport Rates (Reserved)**24.9.6.7 Open Flames and Fuel-Fired Equipment.**

24.9.6.7.1 Wood-fired burners and boilers shall be designed, installed, and operated in a manner that prevents the unintentional ignition of wood or other cellulosic material outside the combustion zone.

24.9.6.7.2* Provisions shall be made to prevent the accumulation of wood and cellulosic dust on the heated surfaces of heating units operating at temperatures exceeding 356°F (180°C).

24.9.6.7.3 An emergency shutoff valve, readily accessible during a fire, shall be provided for flammable fuel lines.

24.9.6.8 Reserved.**24.9.6.9 Reserved.****24.9.6.10 Reserved.****24.9.6.11* Friction and Impact Sparks.**

24.9.6.11.1 Prior to being processed, wood stock shall be inspected for foreign materials, such as nails, sugar taps, fencing wire, and so forth.

24.9.6.11.2 Prevention of foreign materials in particulate size reduction equipment shall be in accordance with 24.9.4.10.

24.9.6.11.3 All equipment shall be designed, installed, and operated to maintain alignment and lubrication to avoid ignition from frictional heating.

24.9.6.11.4* Roller or ball bearings shall be used on all processing and transfer equipment in accordance with 24.9.4.15.1.

24.9.6.11.5 Bushings shall be permitted to be used where an engineering analysis has shown that the mechanical loads and speeds preclude attainment of temperatures sufficient to ignite

wood particulates in the environment of the machines in question.

24.9.6.12 Reserved.**24.9.6.13 Reserved.****24.9.6.14 Electrical Systems.**

24.9.6.14.1 All electrical systems and system components shall be installed in accordance with *NFPA 70*.

24.9.6.14.2* Portions of the facility where dust accumulations occur or where suspensions of wood dust in air could occur shall be equipped with electrical systems and equipment per Article 502 or 503 of *NFPA 70*.

24.9.6.15 Fans and Blowers.

24.9.6.15.1 Requirements for fans and blowers used in pneumatic conveying systems shall be in accordance with 24.9.4.3.2.4.

24.9.6.15.2* Fans that are subject to combustible residue buildup on the fan, fan shroud, and drive mechanism shall be kept clean to prevent overheating and ignition of the deposits.

24.9.6.16* Lighting. Lighting system fixtures shall be designed, installed, and maintained such that they do not pose a potential ignition hazard due to the heat evolved from normal operation or as a result of catastrophic failure or damage.

24.9.6.17 Reserved.**24.9.6.18* Machines and Processing Equipment.**

24.9.6.18.1* Feed-Rate Controls. Feed rates and machine adjustments for the stock being processed on wood cutting, shaping, planing, and sanding operations shall be controlled to prevent ignition (hot cuts).

24.9.6.18.2 Cutter and Abrasive Maintenance.

24.9.6.18.2.1* Wood cutting, shaping, and planing equipment shall be maintained at a level of sharpness to minimize the heat generated from woodworking operations.

24.9.6.18.2.2* Abrasive cutting belts, disc surfaces, and devices shall not be used beyond their design lifetime and shall be replaced or cleaned in the manner specified by the manufacturer when showing signs of loading of the grit.

24.9.6.19 Machinery Setup and Maintenance.

24.9.6.19.1 Provisions shall be made to ensure that machine setup, including but not limited to depth of cut and feed rate, is properly fixed and secure from unintentional change during the production run, consistent with the manufacturer's operation manual.

24.9.6.19.2* Woodworking machines shall be maintained as required in the manufacturer's operation and maintenance manual.

24.9.6.20 Spontaneous Ignition and Chemical Action.

24.9.6.20.1* When storage of wood or wood substitute particulates is employed, the wood or wood substitute particulates shall be evaluated for the potential for spontaneous ignition from chemical reactions during storage.

24.9.6.20.2 Wood or wood substitute particulates that are determined to have a spontaneous ignition potential shall be stored in one of the following locations:

- (1) Outside
- (2) Inside in accordance with Chapter 21
- (3) In separate buildings
- (4) In bins designed such that the particulate flow occurs in a first-in/first-out basis

24.9.6.20.3* Rags, cloths, filter media, or other similar material containing finishing oils that have been determined to have a spontaneous ignition potential shall be disposed of pursuant to 24.8.4.1.8.

24.9.7 Reserved.

24.9.8 Explosion Prevention and Protection.

24.9.8.1 Reserved.

24.9.8.2 Equipment Protection.

24.9.8.2.1 General. (Reserved)

24.9.8.2.2* Dust Collectors with Deflagration Hazards. Dust collectors with a deflagration hazard having a dirty side volume greater than 8 ft³ (0.23 m³) shall be designed and constructed in accordance with one of the following options:

- (1)* Dust collectors constructed of welded steel or other noncombustible material of sufficient strength to withstand the maximum unvented deflagration pressure of the material being collected
- (2)* Dust collectors protected by a listed deflagration suppression system in accordance with NFPA 69 with a design strength exceeding the maximum reduced deflagration pressure of the material being collected
- (3)* Dust collectors equipped with deflagration relief vents in accordance with NFPA 68 with a design strength exceeding the maximum reduced deflagration pressure of the material being collected
- (4) Dust collectors located outdoors and representing minimal exposure to personnel and the public at large with weaker construction, subject to a risk analysis acceptable to the authority having jurisdiction
- (5) Enclosureless dust collectors of any strength suitable for the use intended shall be permitted without any additional explosion protection requirements

24.9.8.2.3* Ducts with a Deflagration Hazard. Ducts having a deflagration hazard shall be designed, constructed, and installed pursuant to one of the following:

- (1)* Ducts, including all access hatches, shall be constructed of metal of sufficient strength to withstand the maximum unvented deflagration pressure of the material being conveyed.
- (2)* Metal ducts shall be protected by a listed deflagration suppression system that has a design strength exceeding the maximum reduced deflagration pressure.
- (3) Metal ducts located indoors shall be equipped with deflagration relief vents and vent ducts designed, installed, and maintained in accordance with NFPA 68 and shall have a design strength exceeding the maximum reduced deflagration pressure.
- (4) Metal ducts located indoors shall be equipped with deflagration relief vents and vent ducts designed, installed, and maintained in accordance with NFPA 68 that exhaust through listed flame-quenching devices and shall have a

design strength exceeding the maximum reduced deflagration pressure.

- (5) Metal ducts located outdoors shall be equipped with deflagration relief vents designed, installed, and maintained in accordance with NFPA 68 and shall have a design strength exceeding the maximum reduced deflagration pressure.
- (6)* Metal ducts that are located outdoors and have weaker construction shall be permitted to be used subject to a risk analysis acceptable to the authority having jurisdiction.

24.9.8.2.4* Silos and Storage Bins with a Deflagration Hazard. Silos and storage bins with a deflagration hazard shall be equipped with either of the following:

- (1) Deflagration relief venting designed to relieve the deflagration to a safe area and maintain the pressure below the yield strength of the vessel
- (2) Explosion suppression systems designed, installed, and maintained in accordance with NFPA 69

24.9.8.2.5* Size Reduction Equipment with a Deflagration Hazard.

24.9.8.2.5.1 Size reduction equipment shall be located in accordance with one of the following:

- (1) Outdoors
- (2) Inside a detached building
- (3) Indoors, separated from other areas by damage-limited construction

24.9.8.2.5.2* Size reduction equipment shall be constructed in accordance with one of the following:

- (1) An enclosure shall be constructed of welded steel or other noncombustible material of sufficient strength to withstand the maximum unvented explosion pressure of the processed material.
- (2) An enclosure shall be constructed of noncombustible material, protected by a listed explosion suppression system with a design strength exceeding the maximum reduced explosion pressure of the processed material.
- (3) An enclosure constructed of noncombustible material, equipped with adequate deflagration relief vents having relief pipes extending outdoors or discharging through listed flame-quenching devices, shall have a design strength exceeding the maximum reduced explosion pressure of the processed material.

24.9.8.2.5.3 Rooms containing the size reduction equipment shall be classified in accordance with Article 500 of *NFPA 70*.

24.9.8.2.6 Conveyors with a Deflagration Hazard.

24.9.8.2.6.1 Enclosed conveyors with a deflagration hazard shall comply with the criteria in 24.9.8.2.2.

24.9.8.2.6.2* Access hatches and removable equipment covers shall be secured with fasteners capable of withstanding design deflagration pressure in accordance with 24.9.8.2.2, unless that hatch or cover is designed to function also as a deflagration relief vent.

24.9.8.2.7 Mixers and Blenders with a Deflagration Hazard. Where an explosion hazard exists as described in Chapter 7, mixers and blenders shall be equipped with either of the following:

- (1) Deflagration relief venting in accordance with NFPA 68

- (2) Explosion protection systems designed, installed, and maintained in accordance with NFPA 69

24.9.8.3 Equipment Isolation.

24.9.8.3.1* Conveying System Isolation.

24.9.8.3.1.1 Conveying systems with deflagration hazards shall be isolated to prevent propagation of fire and deflagration both upstream and downstream into occupied areas or other critical process equipment. (See Annex W.)

24.9.8.3.1.2 Conveying systems with fire hazards shall be protected in accordance with Chapter 9 to prevent fire extension through the facility.

24.9.8.3.1.3* Isolation devices shall be listed or approved for the use intended.

24.9.8.3.1.4 Ducts shall be isolated to prevent propagation of deflagration to other vessels.

24.9.8.3.1.5 Where provided, explosion isolation devices shall be installed, inspected, and maintained in accordance with NFPA 69.

24.9.8.3.2 Dust collectors that discharge into storage bins or silos shall do so in a manner that minimizes the generation of dust clouds.

24.9.8.3.3 The discharge arrangement in 24.9.8.3.2 shall be constructed to minimize dust leaks and shall contain a choke to prevent explosion propagation between the collecting equipment and storage facilities.

24.9.9 Fire Protection.

24.9.9.1 Reserved.

24.9.9.2 Reserved.

24.9.9.3* Fire Extinguishers.

24.9.9.4* Hoses, Standpipes, Hydrants, and Water Supply. (Reserved)

24.9.9.5* Automatic Sprinklers.

24.9.9.6* Detection and Extinguishing Systems. (Reserved)

24.9.9.7 Reserved.

24.9.9.8 Equipment Protection.

24.9.9.8.1 General. (Reserved)

24.9.9.8.2* Dust Collectors with Fire Hazards. Where automatic sprinkler protection is provided in dust collectors, it shall be hydraulically designed to provide a minimum density of 0.20 gpm/ft² (8.15 L/min/m²) over the horizontal projected area of the piece of equipment.

24.9.9.8.3* Ducts with a Fire Hazard. Ducts conveying dry material released by equipment having a high frequency of generated sparks shall be designed and constructed in accordance with one of the following:

- (1) Equipped with a listed spark detection and extinguishing system installed downstream from the last material entry point and upstream of any collection equipment
- (2)* Equipped with a listed spark detection system actuating a high-speed abort gate, provided the abort gate can operate fast enough to intercept and divert burning embers to

atmosphere before they can enter any collection or storage equipment

- (3) If conveying material to locations representing minimal exposure to personnel and the public at large, equipped without spark detection and extinguishing systems but subject to a risk analysis acceptable to the authority having jurisdiction

24.9.9.8.4* Silos and Storage Bins. Where automatic sprinkler protection is provided in bins, hoppers, and silos, the system shall be hydraulically designed to provide a minimum density of 0.20 gpm/ft² (8.15 L/min/m²) over the horizontal projected area of the piece of equipment.

24.9.9.8.5* Size Reduction Equipment with a Fire Hazard. Downstream equipment shall be protected against ignitions caused by size reduction equipment in accordance with 24.9.4.3.

24.9.9.8.6* Conveyors with a Fire Hazard. Where provided, sprinkler protection for rubber belt and other conveyors shall be designed, installed, and maintained in accordance with NFPA 13.

24.9.9.8.7 Mixers and Blenders with Fire Hazards Where automatic sprinkler protection is provided in mixers and blenders, it shall be hydraulically designed to provide a minimum density of 0.20 gpm/ft² (8.15 L/min/m²) over the horizontal projected area of the piece of equipment.

24.10 Emergency Planning and Response. Emergency planning and response shall be in accordance with Chapter 10, NFPA 600, and NFPA 1660.

24.11 Thermal Oil Heating Systems.

24.11.1* Hazard Determination and Design Criteria. Thermal oil heating systems shall be designed, operated, and maintained such that risk of thermal oil spills is minimized, and any fires or explosions resulting from thermal oil spills are extinguished or controlled in a manner that will not cause unacceptable property damage or interruption of production, or unacceptable risk to operating personnel or the public at large.

24.11.1.1 The hazard posed by the thermal oil system, when the oil is used as heat transfer fluid (HTF), shall be determined on the basis of the largest most credible spill quantity of thermal oil, taking into account the following:

- (1)* Total quantity of thermal oil in the system
- (2)* Flow rate of thermal oil through system loops
- (3)* System instrumentation and alarm features that would detect loss of fluid from the system
- (4)* System automatic controls and interlocks, and/or presence of trained operators, that can reliably shut down pumping and/or isolate portions of the system to limit the amount of thermal oil spilled
- (5)* Spatial orientation of thermal oil piping and system components that would allow isolated portions of the system to drain their trapped quantities of thermal oil by gravity

24.11.1.2* The hazards analysis shall define the location, size, and extent of the maximum most credible thermal oil spill, taking into account the following:

- (1) Diversion of a spill due to floor or ground slope
- (2) Containment of a spill by pits, curbs, and dikes
- (3) Relocation of a spill from the immediate area by drains

24.11.1.3 The hazards analysis shall define the fire intensity and duration of the maximum most credible thermal oil spill defined from the analyses in 24.11.1.1 and 24.11.1.2, taking into account the following:

- (1) Rate at which oil will be spilled
- (2) Rate at which oil will drain away
- (3)* Rate at which oil will be consumed during burning
- (4) Heat release rate of the oil spill fire

24.11.1.4 The hazards analysis shall determine the extent of property damage, loss of production, and risk of injury to operating personnel or the public at large from a fire involving the maximum most credible thermal oil spill, taking into account the following:

- (1) Fire resistance of the exposed equipment or structures
- (2) Presence and adequacy of automatic sprinklers or other special extinguishing systems for the duration of the fire
- (3) Presence of fire alarms and means of egress from the vicinity of the fire

24.11.1.5 For vaporizing thermal oil systems, the risk analysis shall additionally determine the extent of property damage, loss of production, and risk of injury to operating personnel or the public at large from a room explosion involving the sudden release of thermal oil vapor or thermal oil heated above its atmospheric boiling point.

24.11.2* General Criteria. Thermal oil shall not be permitted to be pumped throughout a facility to provide building heat except under one of the following conditions:

- (1) All thermal oil piping and points of connection to valves, heat exchangers, or other equipment have welded connections.
- (2) Areas where mechanical joints for thermal oil piping exist are protected with a sprinkler system designed to control a fire in the largest credible thermal oil spill.

24.11.3 Location and Construction.

24.11.3.1 Thermal oil heaters shall be physically separated from adjacent manufacturing areas by locating them in one of the following areas (in order of preference):

- (1) Outdoors where drainage is certain to be away from a building
- (2) In a detached building
- (3) In a building attached to an outside wall of the manufacturing building with the common wall having a 1-hour fire rating
- (4) In a cutoff room at an outside wall of the main production building with the three interior walls having a 1-hour fire rating

24.11.3.2 Nonvaporizing thermal oil heaters with an oil capacity less than 500 gal (1893 L) shall be permitted in manufacturing areas if an oil spill at the heater is controlled according to 24.11.3.3.

24.11.3.3* A vaporizing thermal oil heater shall be located pursuant to the following:

- (1) In compliance with 24.11.3.1
- (2) In a room or building housing having damage-limiting construction to vent an explosion toward a safe area

24.11.3.4 Curbs, dikes, or floor slope combined with drainage to a safe location shall be provided around indoor thermal oil

system components (e.g., storage tanks and pump heat exchangers).

24.11.3.5 Drainage shall not be required when an automatic sprinkler system designed and installed in accordance with NFPA 13 is provided over the containment area and the containment area is designed to hold the largest credible oil spill plus 20 minutes of sprinkler discharge.

24.11.3.6* Where the utilization of ground slope will not increase hazard, ground slope shall be provided under outdoor thermal oil system components that utilize nonwelded mechanical connections to thermal oil circulation piping to divert oil spills to a safe location away from the thermal oil equipment or adjacent buildings.

24.11.3.7* Process control rooms, which are expected to be manned in an emergency, shall be separated from the thermal oil utilization equipment by 1-hour fire-rated construction.

24.11.3.8 At least one path of egress from the control room shall be through an area not susceptible to a fire involving thermal oil.

24.11.4 Heaters.

24.11.4.1 Heaters operating at gauge pressures exceeding 15 psi (103 kPa) shall be designed and operated in conformance with the ASME *Boiler and Pressure Vessel Code*.

24.11.4.2* Pressure relief devices, when provided, shall be piped to discharge oil or vapor to a safe location.

24.11.4.3 Fire detection systems, fire extinguishing systems, or both for an internal heater fire shall be in accordance with Chapter 9.

24.11.5 Piping.

24.11.5.1* Piping shall be securely supported to maintain adequate clearance from combustible construction or other combustible materials.

24.11.5.2* Welded pipe connections shall be used throughout a thermal oil piping system.

24.11.5.3 Bolted mechanical joints shall be permitted to be used at pumps, valves, and equipment connections where the following conditions are met:

- (1) Mechanical joints are protected with a sprinkler system designed to control a fire involving the largest credible thermal oil spill.
- (2) Mechanical joints are insulated and shielded to prevent a leak from becoming a spray fire, and the shielding has a drip hole at the low point to facilitate detection of leaking joints.

24.11.5.4* Where necessary to reduce the largest credible thermal oil spill to an acceptable level, provisions shall be made to isolate the supply and return piping to and from utilization equipment.

24.11.5.5 Copper, cast iron, or plastic piping shall not be used.

24.11.5.6 For systems operating above gauge pressures of 15 psi (103 kPa), pipe materials and types shall be in accordance with ANSI/ASME B31.1, *Power Piping*, or ASME B31.3, *Process Piping*, as applicable.

24.11.5.7* Piping that is routed through production areas where airborne wood particulate can collect on thermal oil

piping shall be insulated to keep surface temperatures below the maximum permitted by 9.4.3.1.

24.11.6 Expansion Tank.

24.11.6.1* Where used as other than an atmospheric tank, expansion tanks shall be designed in accordance with Section VIII of the ASME *Boiler and Pressure Vessel Code*.

24.11.6.2* Expansion tanks that have a breather vent, overflow drain, or pressure relief valve shall have the discharge from these openings piped to a safe location.

24.11.6.3* When necessary to reduce the largest credible thermal oil spill to an acceptable level, the expansion tank shall be provided with a remotely operable drain line that allows the expansion tank to be drained to a safe location.

24.11.6.4* An automatic expansion tank refill system to maintain the thermal oil level in the expansion tank shall not be permitted.

24.11.6.5* Expansion tanks on vaporizing systems or on nonvaporizing systems that heat the oil to within 50 degrees of its atmospheric boiling point shall be provided with an inert gas blanket in the expansion tank vapor space.

24.11.6.5.1 The inert gas blanket shall operate at a pressure between 15 psi and 25 psi (103 kPa and 172 kPa) above the vapor pressure of the heated oil.

24.11.6.5.2 A low-pressure interlock shall be provided that will shut off the heater fuel source if the inert gas pressure drops to less than 15 psi (103 kPa) above the hot oil vapor pressure.

24.11.7* Storage Tanks. Both indoor and outdoor above-ground thermal oil storage tanks shall be constructed, located, and arranged in accordance with NFPA 30.

24.11.8 Safety Controls and Interlocks.

24.11.8.1* All thermal oil systems shall have emergency shutdown and isolation devices in accordance with 24.11.8.1.1 through 24.11.8.1.4.

24.11.8.1.1 Systems that limit the largest credible thermal oil spill shall be interlocked to actuate when any one of the following conditions exist:

- (1) Automatic sprinkler system water flow in any area containing thermal oil heaters, pumps, utilization equipment, or thermal oil piping that is not fully welded at all connecting joints
- (2) Activation of a fire detection system in any area containing thermal oil heaters, pumps, utilization equipment, or thermal oil piping that is not fully welded at all connecting joints
- (3) Activation of the thermal oil leak detection system

24.11.8.1.2 Where an area is equipped with both a fire detection system and an automatic sprinkler system, only one of these shall be required to activate the automatic shutdown and isolation.

24.11.8.1.3 Where an area equipped with fire detection, sprinkler water flow, or thermal oil loss can be positively identified by the arrangement and/or control system of the detection devices, only those automatic shutdown and isolation devices required to stop thermal oil flow into and out of the affected area shall be required to be interlocked for automatic actuation.

24.11.8.1.4 Where an area subject to a thermal oil spill is under constant observation by operators or personnel who are trained to respond and have access authority to manually activate the required thermal oil system shutdown and isolation, then automatic shutdown by sprinkler water flow shall not be required for that area.

24.11.8.2* An accessible, manual, remote emergency shutoff switch shall be provided that is capable of safely shutting down and isolating the heat transfer system in the configuration required to limit the largest credible thermal oil spill.

24.11.9 Fuel Burner Controls and Interlocks.

24.11.9.1 Oil or gas-fired heaters shall be designed and installed in accordance with the applicable requirements of NFPA 85.

24.11.9.2 Wood dust suspension burners shall be designed and installed in accordance with the applicable requirements of NFPA 85.

24.11.9.3* Heaters that burn wood waste in a fluidized bed or on a grate shall provide a means to prevent the accumulation of explosible concentrations of combustibles in the heater or in any stack gas utilization equipment, following a shutdown with unburned fuel in the heater.

24.11.9.4* If stack gas from the thermal oil heater is recovered to provide auxiliary base load heat for other equipment (e.g., rotary dryers), a means shall be provided to ensure that all equipment is properly purged prior to an attempt being made to ignite a burner on any of the interconnected equipment.

24.11.9.4.1 Temperature and pressure monitoring shall be required for dryer exhaust recirculation into the thermal oil heater.

24.11.9.4.2 Temperature and pressure monitoring shall be required for flue gas recycling into the thermal oil heater.

24.11.9.5 Where solid fuel central energy systems provide hot air stream to more than one user, one of which is a thermal oil heating system, they shall be permitted to be designed to reduce the hot air stream feeding the thermal oil heating system, without the need to shut down the fuel source.

24.11.9.6* Instrumentation and interlocks shall be provided to sound an alarm and automatically shut off the fuel source or the heat source to the thermal oil heater when any of the following conditions are detected:

- (1) Low thermal oil flow or pressure at the heater outlet
- (2) High thermal oil temperature or pressure at the heater outlet
- (3) Low oil level in expansion tank and, if provided, any other signal indicating loss of thermal oil from the system
- (4) Low liquid thermal oil level in heater (vaporizing systems only)
- (5) Activation of a fire detection system, extinguishing system, or both, for the heater heat exchanger, if provided

24.11.10 Operational Considerations.

24.11.10.1 Any and all system leaks that are discovered shall be promptly corrected with permanent repairs, regardless of the size of the leak.

24.11.10.2 Any spilled oil shall be cleaned up promptly.

24.11.10.3 Any pipe or equipment insulation that is discovered to be oil-soaked shall be promptly removed and replaced with clean, oil-free insulation.

24.11.10.4* If it is suspected that the material being heated is infiltrating into the thermal oil loop, the system shall be immediately shut down to find and repair the leakage.

24.11.10.5* Operators shall be trained at least annually in proper operation of the thermal oil system, including recognition and proper response to upset conditions that could lead to dangerous situations.

24.11.10.6 Safety interlocks shall be inspected, tested, and calibrated at least annually to keep them in proper operating condition.

24.11.10.7* The physical properties of the thermal oil shall be tested and documented annually, with replacement of all oil in the system when recommended by the oil manufacturer.

24.11.11* Fire Protection.

24.11.11.1 Automatic sprinkler protection meeting the requirements of NFPA 13 for Extra Hazard Group 1 occupancies shall be provided for building areas containing heat transfer system heaters, vaporizers, equipment using thermal oil, plenums, or any other areas where a hot oil spill could accumulate.

24.11.11.2* Heaters shall be provided with a means to detect and automatically extinguish a thermal oil spill fire in the fire box or heat exchanger section where spilled oil would collect unless the system complies with one of the following:

- (1) Systems contain less than 2000 gal (7571 L) of thermal oil, subject to a risk analysis that is acceptable to the authority having jurisdiction.
- (2) Heaters have a fire detection system interlocked to physically isolate the heater from the external thermal oil piping.
- (3) Instrumentation is present to alert operators of an oil fire in the heater and operators constantly monitor conditions in the heater and are trained to actuate a manual extinguishing system.

24.11.11.3* Activation of a heater fire extinguishing system shall automatically stop the primary thermal oil circulation pumps unless the system complies with both of the following:

- (1) The heater contains a bed of wood waste fuel or the refractory inside the heater can retain enough heat to cause thermal oil breakdown and tube fouling if fluid circulation through the unit is stopped.
- (2) The primary loop system has an emergency bypass with an oil cooling heat exchanger to rapidly reduce oil temperature.

24.12 Storage.

24.12.1 General. Except as modified in Section 24.12, storage shall be in accordance with NFPA 13.

24.12.1.1 Dry Lumber. Where protected, indoor storage of lumber, panelboard, stuck lumber, dense pack lumber, and

veneer shall be protected in the same manner as a Class II commodity in accordance with NFPA 13.

24.12.1.2 Green Lumber. Where the moisture content is greater than or equal to 25 percent (wet basis), the stored materials shall be protected in the same manner as a Class I commodity in accordance with NFPA 13.

24.12.1.3 Ignitable (Flammable and Combustible) Liquid Storage. Design protection for bulk and container storage shall be in accordance with NFPA 30.

24.12.2 Indoor Dry, Fine Particulate Storage.

24.12.2.1* Damage-limiting construction to relieve to a safe area shall be used for buildings storing dry, fine particulates where a deflagration hazard exists.

24.12.2.2 Construction shall minimize horizontal ledges where dust can accumulate.

24.12.2.3* Where provided, sprinkler piping shall be protected against explosion damage.

24.12.2.4 Any areas storing dry wood particulate shall have Class II, Division 1 electrical equipment.

24.12.2.5 Detached buildings that store only green wood particulate shall be permitted to have electrical equipment suitable for Class II, Division I; or Class II, Division 2 hazardous areas in accordance with Article 500 of *NFPA 70*.

24.12.2.6 Powered front-end loaders used for material reclaim shall comply with 9.4.4.

24.12.3 Wood Scrap or Wood Waste Processing and Disposal.

24.12.3.1 Section 24.12.3 shall apply to the processing and disposal of wood scrap or wood waste for fuel and other purposes.

24.12.3.2 If scrap or waste wood is to be processed by hogs delivering small chips and shredded product, the discharge from such processing shall comply with the requirements in Chapter 9 for dust-collecting systems.

24.12.3.3 Metal detectors interlocked to shut down the flow of material or magnetic separators shall be installed upstream of wood hogs and chippers.

24.12.3.4 Wood scrap or wood waste processed by mills delivering a pulverized product shall comply with the requirements of 24.9.4.10.

24.12.3.5 Boilers, furnaces, and thermal oil heating systems using wood scrap or wood waste as fuel shall comply with the applicable sections of NFPA 85.

24.12.3.6 Where wood scrap or wood waste is disposed of in an incinerator, the incinerator shall be in accordance with the requirements of NFPA 82.

24.13 Special Considerations. (Reserved)

Chapter 25 Combustible Dusts and Particulate Solids Not Otherwise Specified

25.1 Administration.

25.1.1* Scope.

25.1.1.1 This chapter shall apply to combustible dusts and particulate solids not otherwise covered by Chapters 21, 22, 23, or 24.

25.1.1.2* This chapter provides requirements for all phases of the manufacturing, processing, blending, conveying, repackaging, and handling of combustible dusts and particulate solids or hybrid mixtures, regardless of concentration or particle size, where the materials present a fire, a flash fire, or an explosion hazard.

25.1.1.3 This chapter includes specific requirements for additive manufacturing.

25.1.2 Reserved.

25.1.3 Application. This chapter shall modify and augment the requirements of Chapters 1 through 10.

25.2 Reserved.

25.3 Reserved.

25.4 Reserved.

25.5 Hazard Identification. The materials handled in the facility shall be evaluated for their hazard in accordance with Chapter 5.

25.6 Reserved.

25.7 Dust Hazards Analysis (DHA).

25.7.1 General Requirements. The facility and process equipment shall be evaluated for dust or particulate solid fire, flash fire, and explosion hazards in accordance with this section.

25.7.1.1 Retroactivity. The hazard assessment shall be conducted in accordance with the retroactivity provisions in Section 7.1.

25.7.2 Reserved.

25.7.3 Methodology.

25.7.3.1 General.

25.7.3.1.1 In addition to areas addressed in 7.3.4.2.1, those portions of the process and facility interior where dust accumulations exist external to equipment in sufficient depth to prevent discerning the underlying contrasting surface color shall be evaluated to determine if a dust flash fire or explosion hazard exists.

25.7.3.1.2 Reserved.

25.7.3.1.3* The threshold housekeeping dust accumulation limits defining dust flash fire or explosion hazard areas shall be determined in accordance with any one of the following four methods:

- (1) Layer depth criterion method in 25.7.3.5
- (2) Mass method A in 25.7.3.6
- (3) Mass method B in 25.7.3.7
- (4) Risk assessment method in 25.7.3.8

25.7.3.1.4 Each of the methods in 25.7.3.5, 25.7.3.6, 25.7.3.7, and 25.7.3.8 shall be deemed to provide equivalent levels of safety.

25.7.3.1.5* It shall be permitted to determine the accumulated mass and bulk density on a dry weight basis by drying the sample to less than or equal to 5 percent moisture by weight.

25.7.3.1.6 Dust accumulations are deemed nonseparated unless segregation, separation, or detachment is used to limit the hazard area in accordance with 9.3.5 and 25.9.3.5.

25.7.3.1.7 All dust accumulated on structures above the lowest footprint shall be evaluated as if accumulated on the lowest footprint.

25.7.3.1.8 Dust accumulation amounts shall reflect the conditions that exist just prior to routinely scheduled cleaning and shall not include short-term accumulations cleaned in accordance with Chapter 8 and Section 25.8.

25.7.3.1.9 Personnel exposed to a dust flash fire hazard shall be protected in accordance with 8.3.2 and Section 8.6.

25.7.3.1.10 Those portions of the facility and process where a dust flash fire or explosion hazard exists shall be protected from the effects of those hazards in accordance with this section as well as Section 9.3, 25.9.3, Chapter 7, and Section 25.7.

25.7.3.2 Reserved.

25.7.3.3 Reserved.

25.7.3.4 Reserved.

25.7.3.5* Layer Depth Criterion Method. A dust flash fire or dust explosion hazard area exists when the average dust layer thickness measured external to process equipment over the compartment area exceeds the quantity determined in 25.7.3.5.1 and 25.7.3.5.2.

25.7.3.5.1 The layer depth criterion, which is $\frac{1}{32}$ in. (0.8 mm), shall be permitted to be increased according to the following equation for materials with bulk density less than 75 lb/ft³ (1200 kg/m³):

[25.7.3.5.1]

$$LD \text{ (in.)} = \frac{\left(\frac{1}{32} \text{ in.}\right) \left(75 \frac{\text{lb}}{\text{ft}^3}\right)}{BD}$$

where:

LD = layer depth (in.)

BD = bulk density (lb/ft³)

25.7.3.5.2* A dust explosion hazard and dust flash fire hazard shall be deemed to exist in any building or room where any of the following conditions exists:

- (1) The total area of nonseparated dust accumulations exceeding the layer depth criterion is greater than 5 percent of the footprint area
- (2) The area of any single nonseparated dust accumulation exceeding the layer depth criterion is greater than 1000 ft² (92.9 m²)

- (3) The total volume of nonseparated dust accumulations is greater than the layer depth criterion multiplied by 5 percent of the footprint area
- (4) The total volume of any single nonseparated dust accumulation is greater than the layer depth criterion multiplied by 1000 ft² (92.9 m²)

25.7.3.6* Mass Method A. A dust flash fire or dust explosion hazard area exists when the total accumulated dust external to process equipment exceeds the quantities determined from the equations in 25.7.3.6.1 and 25.7.3.6.2.

25.7.3.6.1 The threshold dust mass establishing a building or room as a dust explosion hazard area, $M_{basic-exp}$, shall be determined by the following equation:

$$M_{basic-exp} = 0.004 \cdot A_{floor} \cdot H \quad [25.7.3.6.1]$$

where:

$M_{basic-exp}$ = threshold dust mass (kg) based on building damage criterion

A_{floor} = lesser of enclosure floor area (m²) or 2000 m²

H = lesser of enclosure ceiling height (m) or 12 m

25.7.3.6.2 The threshold dust mass establishing a building or room as a dust flash fire hazard area, $M_{basic-fire}$, shall be determined by the following equation:

$$M_{basic-fire} = 0.02 \cdot A_{floor} \quad [25.7.3.6.2]$$

where:

$M_{basic-fire}$ = threshold dust mass (kg) based on personnel fire exposure criterion

A_{floor} = lesser of enclosure floor area (m²) or 2000 m²

25.7.3.7* Mass Method B. A dust flash fire or dust explosion hazard area exists when the total accumulated dust external to process equipment exceeds the quantities determined from the equations in 25.7.3.7.1 and 25.7.3.7.2.

25.7.3.7.1* The threshold dust mass establishing a building or room as a dust explosion hazard area, M_{exp} , shall be determined by the following equation:

$$M_{exp} = \left[\frac{P_{es}}{DLF} \right] \cdot \left[\frac{C_w}{P_{max}} \right] \cdot \frac{A_{floor} \cdot H}{\eta_D} \quad [25.7.3.7.1]$$

where:

M_{exp} = threshold dust mass (kg) based on building damage criterion

P_{es} = enclosure strength evaluated based on static pressure calculations for the weakest building structural element not intended to vent or fail (bar g) per NFPA 68

DLF = dynamic load factor, the ratio of maximum dynamic deflection to static deflection per NFPA 68

C_w = worst-case dust concentration (kg/m³) at which the maximum rate-of-pressure-rise results in tests conducted per ASTM E1226

P_{max} = maximum pressure (bar g) developed in ASTM E1226 tests with the accumulated dust sample

A_{floor} = enclosure floor area (m²)

H = enclosure ceiling height (m)

η_D = entrainment fraction = 0.25

25.7.3.7.1.1 In the absence of detailed structural response analysis, it shall be permitted to assume a worst-case value of $DLF = 1.5$ and design based on the weakest structural element of the enclosure.

25.7.3.7.1.2* It shall be permitted to use an alternative value of η_D based on a risk assessment that is acceptable to the AHJ.

25.7.3.7.2* The threshold dust mass establishing a building or room as a dust flash fire hazard area, M_{fire} , shall be determined by the following equation:

$$M_{fire} = \rho \cdot C_w \cdot \left[\frac{P_{initial}}{P_{initial} + P_{max}} \right] \cdot \frac{A_{floor} \cdot D}{\eta_D} \quad [25.7.3.7.2]$$

where:

M_{fire} = threshold dust mass (kg) based on personnel fire exposure criterion

ρ = probability of flame impingement on a person, not to exceed 0.05 (5 percent probability)

C_w = worst-case dust concentration (kg/m³) at which the maximum rate-of-pressure-rise results in tests conducted per ASTM E1226

$P_{initial}$ = 1 bar absolute

P_{max} = maximum pressure (bar g) developed in ASTM E1226 tests with the accumulated dust sample

A_{floor} = enclosure floor area (m²)

D = nominal height of a person (2 m)

η_D = entrainment fraction = 0.25

25.7.3.7.2.1* It shall be permitted to use an alternative value of η_D , based on a risk assessment that is acceptable to the AHJ.

25.7.3.8* Risk Assessment Method. A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine whether or where a dust explosion hazard or dust flash fire hazard area exists.

25.8 Management Systems.

25.8.1 Reserved.

25.8.2 Reserved.

25.8.3 Reserved.

25.8.4 Housekeeping.

25.8.4.1 Reserved.

25.8.4.2 Reserved.

25.8.4.3 Reserved.

25.8.4.4 Reserved.

25.8.4.5 Reserved.

25.8.4.6 Frequency and Goal.

25.8.4.6.1* See 8.4.6.3.

25.8.4.6.2* Where the facility is intended to be operated with more than the dust accumulation limit defined by the owner/operator's chosen criterion in 25.7.3, a documented risk assess-

ment acceptable to the AHJ shall be permitted to be conducted to determine the allowable dust accumulation consistent with the design basis of any fire, flash fire, or explosion protection measures provided in accordance with 25.8.3 and 25.9.3.2.4.

25.8.5 Reserved.

25.8.6 Reserved.

25.8.7 Inspection, Testing, and Maintenance.

25.8.7.1 Reserved.

25.8.7.2 Specific Equipment Maintenance.

25.8.7.2.1 Maintenance of Material Feeding Devices.

25.8.7.2.1.1 Bearings shall be lubricated and checked for excessive wear on a periodic basis.

25.8.7.2.1.2 If the material has a tendency to adhere to the feeder or housing, the components shall be cleaned periodically to maintain good balance and minimize the probability of ignition.

25.8.7.2.2 Maintenance of Air-Moving Devices.

25.8.7.2.2.1 Fans and blowers shall be checked periodically for excessive heat and vibration.

25.8.7.2.2.2 Maintenance, other than the lubrication of external bearings, shall not be performed on fans or blowers while the unit is operating.

25.8.7.2.2.3 Bearings shall be lubricated and checked periodically for excessive wear.

25.8.7.2.2.4* If the material has a tendency to adhere to the rotor or housing, the components shall be cleaned periodically to maintain good balance and minimize the probability of ignition.

25.8.7.2.2.5* The surfaces of fan housings and other interior components shall be maintained free of rust.

25.8.7.2.2.6 Aluminum paint shall not be used on interior steel surfaces.

25.8.7.2.3 Maintenance of Air-Material Separators.

25.8.7.2.3.1 Means to Dislodge.

(A) Air-material separation devices that are equipped with a means to dislodge particulates from the surface of filter media shall be inspected periodically as recommended in the manufacturers' instructions for signs of wear, friction, or clogging.

(B) These devices shall be adjusted and lubricated as recommended in the manufacturers' instructions.

25.8.7.2.3.2 AMSs that recycle air (i.e., cyclones and filter media dust collectors) shall be maintained to comply with 9.4.4.6.3.

25.8.7.2.3.3 Filter media shall not be replaced with an alternative type unless a thorough evaluation of the fire hazards has been performed, documented, and reviewed by management.

25.8.7.2.4 Maintenance of Abort Gates. Abort gates shall be adjusted and lubricated as recommended in the manufacturers' instructions.

25.8.7.2.5 Maintenance of Fire and Explosion Protection Systems.

25.8.7.2.5.1 All fire detection equipment monitoring systems shall be maintained in accordance with the requirements of NFPA 72.

25.8.7.2.5.2 All fire-extinguishing systems shall be maintained pursuant to the requirements established in the standard that governs the design and installation of the system.

25.8.7.2.5.3* All vents for the relief of pressure caused by deflagrations shall be maintained.

25.8.7.2.5.4 All explosion prevention systems and inerting systems shall be maintained pursuant to the requirements of NFPA 69.

25.8.7.3 Impairments of Fire Protection and Explosion Prevention Systems.

25.8.7.3.1* Impairments shall include anything that interrupts the normal intended operation of the fire protection or explosion prevention system.

25.8.7.3.2* A written impairment procedure shall be followed for every impairment to the fire protection or explosion prevention system.

25.8.7.3.3* Impairments shall be limited in size and scope to the system or portion thereof being repaired, maintained, or modified.

25.8.7.3.4* Impairment notification procedures shall be implemented by management to notify plant personnel and the AHJ of existing impairments and their restoration.

25.8.8 Reserved.

25.8.9* Contractors. Contractors involved in the commissioning, repair, or modification of explosion protection equipment shall be qualified as specified in NFPA 69.

25.8.9.1 Reserved.

25.8.9.2 Reserved.

25.8.9.3* Contractor Training. Documentation shall be maintained detailing the training that was provided and who received it.

25.9 Hazard Management: Mitigation and Prevention

25.9.1 Reserved.

25.9.2 Reserved.

25.9.3 Building Design.

25.9.3.1 Construction.

25.9.3.1.1 Interior walls erected for the purpose of limiting fire spread shall be designed in accordance with NFPA 221 and have a minimum 1-hour fire resistance rating.

25.9.3.1.2* Floors and load-bearing walls that are exposed to dust explosion hazards shall be designed to preclude failure during an explosion.

25.9.3.2 Building or Building Compartment Protection.

25.9.3.2.1 Reserved.

25.9.3.2.2 Fire Resistance Rating.

25.9.3.2.2.1 Interior stairs and elevators shall be enclosed in shafts designed to prevent the migration of dust and that have a minimum fire resistance rating in accordance with NFPA 101.

25.9.3.2.2.2* Doors that are the automatic-closing or self-closing type and that have a minimum fire protection rating of 1 hour shall be provided at each landing.

25.9.3.2.2.3 Stairs, elevators, and manlifts that serve only open-deck floors, mezzanines, and platforms shall not be required to be enclosed.

25.9.3.2.3 Protection of Openings and Penetrations.

25.9.3.2.3.1 Where floors, walls, ceilings, and other partitions have been erected to control the spread of fire or deflagrations, penetrations in these structures shall be sealed to maintain their fire resistance rating and their physical integrity in a deflagration. (See 9.4.6.3.)

25.9.3.2.3.2 Openings in fire walls and in fire barrier walls shall be protected by self-closing fire doors that have a fire protection rating, when tested in accordance with NFPA 252, equivalent to the wall design.

25.9.3.2.3.3 Fire doors shall be installed according to NFPA 80 and shall normally be in the closed position.

25.9.3.2.4* Deflagration Venting of Buildings or Building Compartments.

25.9.3.2.4.1* If a building or building compartment contains a dust explosion hazard area external to protected equipment as specified in 25.7.3.1.2 or 25.7.3.1.3, the building or building compartment shall be provided with deflagration venting in accordance with NFPA 68.

25.9.3.2.4.2* Vent Closures.

(A) Vent closures shall be directed toward a restricted area.

(B) The vent closure shall not be a missile hazard.

(C) The fireball and the blast pressure that are created by the venting process shall not impinge on unrestricted personnel pathways.

25.9.3.3 Life Safety.

25.9.3.3.1 Means of egress shall comply with NFPA 101.

25.9.3.3.2* Means of egress for buildings or building compartments that contain a deflagration hazard area shall be designed in accordance with Section 7.11 of NFPA 101.

25.9.3.4 Reserved.

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

25.9.3.5.1 General. Areas in which combustible dusts are produced, processed, handled, or collected such that combustible dust accumulation on exposed or concealed surfaces, external to equipment or containers, exceeds the threshold as determined in 25.7.3, shall be detached, segregated, or separated from other occupancies to minimize damage from a fire or explosion.

25.9.3.5.2 Use of Segregation.

25.9.3.5.2.1* Physical barriers that are erected to segregate dust flash fire hazards areas, including seals at all penetrations of floors, walls, ceilings, or partitions, shall have a minimum 1-hour fire resistance rating.

25.9.3.5.2.2 Doors and openings shall not be permitted in physical barriers unless they are normally are closed and have at least the strength and fire resistance rating required of the physical barrier. These doors shall be installed according to NFPA 80.

25.9.3.5.3 Use of Separation.

25.9.3.5.3.1* See 9.3.5.3.1.

25.9.3.5.3.2 Where separation is used to limit a dust explosion hazard or dust flash fire hazard area, dust thresholds in 25.7.3 shall be determined for this limited area such that the parameter A_{floor} in the equations in 25.7.3 is consistent with the limited area under consideration.

25.9.4 Equipment Design.

25.9.4.1* General.

25.9.4.1.1 Equipment shall be maintained and operated in a manner that minimizes the escape of dust.

25.9.4.1.2 Methods of fire and explosion protection for specific equipment shall be in accordance with this section.

25.9.4.1.3* Systems for the pre-deflagration detection and control of ignition sources, installed in accordance with NFPA 69 shall be permitted to be used to reduce the probability of occurrence of a deflagration in the following:

- (1) In ductwork supplying AMS
- (2) In recycled air from AMS to a building
- (3) In ductwork between process equipment

25.9.4.2 Reserved.

25.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.

25.9.4.3.1 General.

25.9.4.3.1.1 The design of the system shall be documented, and the documentation shall include the following information:

- (1) Data on the range of particulate size
- (2) Concentration of combustible dust in the conveyance air stream
- (3) Potential for reaction between the transported particulates and the extinguishing media used to protect process equipment
- (4) Conductivity of the particulates
- (5) Other physical and chemical properties that could affect the fire protection of the process

25.9.4.3.1.2 All system components that handle combustible particulate solids shall be designed to be dusttight, except for openings designed for intake and discharge of air and material.

25.9.4.3.1.3* Where more than one material is to be handled by a system, compatibility tests shall be run.

25.9.4.3.1.4 Where incompatibility is found, provisions shall be made for cleaning the system prior to transporting a new material.

25.9.4.3.1.5 Where the materials being conveyed are corrosive, the system shall be constructed of corrosion-resistant materials.

25.9.4.3.1.6 Where the atmosphere surrounding the conveying system is corrosive, the conveying system shall be constructed of corrosion-resistant materials.

25.9.4.3.2* Specific Requirements For Pneumatic Conveying Systems.

25.9.4.3.3 Specific Requirements for Dust Collection Systems.

25.9.4.3.3.1 Manifolded branches serving equipment presenting a deflagration hazard shall be isolated in accordance with 9.8.3.

25.9.4.3.3.2* Dust collection ducts from a single piece of equipment or from multiple pieces of equipment interconnected on the same process stream shall be permitted to be manifolded without explosion isolation on the branches.

25.9.4.3.4 Specific Requirements for Centralized Vacuum Cleaning Systems. Dust collection ducts for centralized vacuum cleaning systems shall be permitted to be manifolded without explosion isolation on the branches.

25.9.4.4 Air-Material Separators (Air Separation Devices).

25.9.4.4.1 General.

25.9.4.4.1.1* The clean air-plenum of an AMS shall be considered a hazardous (classified) location.

25.9.4.4.1.2 Reserved.

25.9.4.4.1.3 Incompatible Materials. Where more than one material is to be handled by a system and is known to be incompatible, provisions shall be made for cleaning the system prior to the handling of a new material.

25.9.4.4.2 Reserved.

25.9.4.4.3 Reserved.

25.9.4.4.4 Enclosureless AMS. See 25.9.4.4.5.

25.9.4.4.5* AMS Locations. The requirement of 9.4.4.5.1 shall not apply to enclosureless AMSs meeting all of the following criteria:

- (1) The filter medium is not shaken or pressure-pulsed to dislodge dust during operation.
- (2) The AMS is not used to vent or serve metal grinders, hot work processes, or machinery that can produce sparks.
- (3) The AMS is not used to vent or serve sanders, abrasive planers, or similar sanding process equipment.
- (4)* Each collector system has a maximum air flow-handling capacity of 5000 cfm (2.4 m³/sec).
- (5)* The fan motor is suitable for Class II or Class III, Division 2, as appropriate, or Zone 22.
- (6) The collected dust is removed daily or at a frequency sufficient to ensure efficient operation and to limit the collected dust to less than 22 lb (10 kg).
- (7) The collector is located at least 20 ft (6.1 m) from any means of egress or area routinely occupied by personnel.
- (8)* Multiple collectors in the same room are separated from each other by at least 20 ft (6.1 m).
- (9)* The minimum ignition energy (MIE) of the collected materials is greater than 500 mJ.

(10) The fan construction is spark resistant and meets the criteria in 9.4.5.4.

(11) The filter medium is not located within 35 ft (10.7 m) of any open flame or hot surface capable of igniting a dust cloud of the material it contains.

25.9.4.4.6 AMS Clean Air Exhaust.

25.9.4.4.6.1* A flame-arresting and particulate-retention device that is designed for use on deflagration vent discharge shall not be used as an explosion isolation device in a return air line.

25.9.4.4.7 AMS Construction.

25.9.4.4.7.1* In addition to the requirements for access doors in 9.4.4.7.7, access doors not designed to be used as deflagration venting shall be designed to withstand the vented explosion pressure (P_{red}).

25.9.4.5* Air-Moving Devices (Fans and Blowers).

25.9.4.5.1* The requirement of 9.4.5.2 shall not apply to systems where both of the following requirements are met:

- (1) The system is designed to operate at a combustible particulate solids concentration less than 10 percent of the MEC of the dust.
- (2) Hybrid mixtures are not present.

25.9.4.5.2 Where a fire hazard exists and where combustible particulate solids pass through an AMD, provisions shall be made to prevent ignited material from entering processes downstream, in accordance with Section 9.9.

25.9.4.6 Duct Systems.

25.9.4.6.1 Ductwork shall be constructed of metal or noncombustible, conductive material in accordance with 9.6.6.1 and 25.9.6.6.1.

25.9.4.6.2* Flexible hose and connections shall be permitted in the minimum length necessary to achieve functions such as but not limited to material pickup, material transfer, vibration isolation, weigh bin isolation, or equipment movement in accordance with 9.6.6 and 25.9.6.6.

25.9.4.7 Reserved.

25.9.4.8* Abort Gates.

25.9.4.8.1* Construction.

25.9.4.9 Bulk Storage Enclosures.

25.9.4.9.1 Reserved.

25.9.4.9.2* Construction. Bulk storage containers, 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.

25.9.4.9.3 Reserved.

25.9.4.9.4 Reserved.

25.9.4.9.5* Access Doors and Openings.

25.9.4.9.6 Explosion Hazards and Protection.

25.9.4.9.6.1 Where an explosion hazard exists, intertank or interbin venting shall not be permitted.

25.9.4.9.6.2 Where an explosion hazard exists, fixed bulk storage containers shall be protected in accordance with 25.9.8.2.

25.9.4.9.6.3* The explosion protection requirements of 25.9.8.2 shall not be required provided that the volume of the fixed bulk storage container is less than 8 ft³ (0.2 m³).

25.9.4.10 Size Reduction.

25.9.4.10.1 Where an explosion hazard exists, protection shall be provided as specified in 25.9.8.2.

25.9.4.10.2 Where a fire hazard exists, protection shall be provided in accordance with Section 9.9.

25.9.4.11 Particle Size Separation.

25.9.4.11.1 Connection ducts shall be in conformance with 9.4.6 and 25.9.4.6.

25.9.4.11.2 Where an explosion hazard exists, protection shall be provided as specified in 25.9.8.2.

25.9.4.11.3* Screens and sieves shall not be required to have explosion protection.

25.9.4.11.4 Where a fire hazard exists, protection shall be in accordance with Section 9.9.

25.9.4.12 Pressure Protection Systems.

25.9.4.12.1 Reserved.

25.9.4.12.2* Pressure Relief Devices.

25.9.4.13* Mechanical Feeding Devices. When failure of a mechanical feeding device could cause significant combustible dust hazards, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

25.9.4.13.1 Controls shall be provided to monitor the operation status of the equipment.

25.9.4.14* Bucket Elevators.

25.9.4.14.1 Casing, head and boot sections, access openings, and connecting spouts shall be as dusttight as practicable and shall be constructed of noncombustible materials.

25.9.4.14.2* Inspection openings shall be provided in the boot section to allow clean-out of the boot and inspection of the alignment of the boot pulley and belt.

25.9.4.14.3 Inspection openings shall be provided in the head section to allow complete inspection of the head pulley lagging, the belt and pulley alignment, and the discharge throat of the leg.

25.9.4.14.4* Each leg shall be independently driven by motor(s) and drive train(s) capable of handling the full-rated capacity of the elevator leg without overloading.

25.9.4.14.4.1 Multiple motor drives shall be interlocked to prevent operation of the leg upon failure of any single motor.

25.9.4.14.4.2 The drive shall be capable of starting the unchoked leg under full (100 percent) load.

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

25.9.4.14.6* The use of plastic, rubber, and other combustible linings shall be limited to high-impact areas and wear surfaces.

25.9.4.14.7 The leg head section between the up and down casings shall be sloped at an angle of not less than 45 degrees.

25.9.4.14.8 All spouts shall be designed and installed to handle the full-rated elevating capacity of the largest leg feeding such spouts.

25.9.4.14.9 Legs shall have lagging installed on the head pulley to minimize slippage.

25.9.4.14.10 Leg conveyor belts and lagging shall have a surface electrical resistivity not greater than 300 megaohms per square (3 x 10⁸ ohms per square). (*See A.21.9.4.15.5.*)

25.9.4.14.11 Leg belts and lagging shall be fire resistant and oil resistant.

25.9.4.14.11.1 Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 18.65, or the flame test for belting in Part 13.2 of ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*.

25.9.4.14.12* Monitors.

25.9.4.14.12.1 Where determined necessary by the DHA, monitors shall be provided at head, tail, and knee pulley bearings that indicate high bearing temperature or vibration detection.

25.9.4.14.12.2 Where determined necessary by the DHA, monitors shall be provided for head, tail, and knee pulley alignment and belt alignment.

25.9.4.14.12.3 Abnormal conditions shall actuate a visual or an audible and visual alarm requiring corrective action.

25.9.4.14.13 Explosion Prevention/Protection. Where an explosion hazard exists, protection of bucket elevator legs shall be in accordance with Section 9.8 and 25.9.8.

25.9.4.15* Conveyors and Spouts.

25.9.4.15.1 Housing and Coverings.

25.9.4.15.1.1 Where an explosion hazard exists within enclosed conveyors, they shall be protected in accordance with 25.9.8.2.

25.9.4.15.1.2 Housings for enclosed conveyors shall be of metal construction and shall be designed so as to prevent escape of combustible dusts.

(A) Flexible screw conveyors utilizing nonmetal housing shall be permitted to be used provided the requirements of 9.6.6.1.2 are met.

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

25.9.4.15.2 Power Shutoff.

25.9.4.15.2.1* 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.

25.9.4.15.2.2 The alarm specified in 25.9.4.15.2.1 shall alert operators, and feed to the conveyor shall be stopped or diverted.

25.9.4.16* Mixers and Blenders. When failure of a mixing/blending device could cause significant combustible dust hazards, a method shall be provided to prevent the hazardous conditions and stop continued operation of the equipment.

25.9.4.16.1 Mixers and blenders shall be designed to control fugitive dust emissions.

25.9.4.16.2* Foreign materials that can become ignition sources shall be prevented from entering the mixer or blender.

25.9.4.16.3 Where an explosion hazard exists, protection shall be provided as specified in 25.9.8.2.

25.9.4.16.4 Where a fire hazard exists, protection shall be in accordance with Section 9.9.

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

25.9.4.17* Dryers.

25.9.4.17.1 Drying Media. 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.

25.9.4.17.2 Where an explosion hazard exists, protection shall be provided as specified in 25.9.8.2.

25.9.4.17.3 Where a fire hazard exists, protection shall be in accordance with Section 9.9.

25.9.4.18 Reserved.

25.9.4.19 Additive Manufacturing.

25.9.4.19.1 General Requirements.

25.9.4.19.1.1 Additive manufacturing shall comply with the additional requirements of this section.

25.9.4.19.1.2 Additive manufacturing involving metal powders shall be covered by Chapter 22.

25.9.4.19.1.3 Verification of the grounding and bonding of portable equipment shall be done before each use.

25.9.4.19.1.4 Containers used for conductive particulate solids shall be conductive or static dissipative.

(A) Conductive and static-dissipative powder containers shall be bonded to the equipment prior to the transfer of powder to and from such equipment.

25.9.4.19.1.5 Control measures shall be provided to avoid the creation of suspended dust clouds during transfer of powder to and from equipment.

25.9.4.19.1.6 Portable vacuum cleaning units and portable dust collection equipment shall be listed for use in a Class II atmosphere.

25.9.4.20 Ultrafine Particles.

25.9.4.20.1* General. The processing, handling, and storage of ultrafine particles shall also follow the requirements of this section.

25.9.4.20.2 If testing of a mixture or particle size distribution that includes ultrafine particles shows that the explosibility characteristics are similar to the micrometer particles the requirements of 25.9.4.20 shall not apply.

25.9.4.20.3* The DHA performed for processes or facilities that handle ultrafine particles shall include an assessment of the hazards associated with the difficulty of containing and controlling ultrafine particles in the equipment and processes involved in addition to the fire and deflagration hazards customarily addressed.

25.9.4.20.4 The DHA shall include a determination of the appropriate effective fire and explosion protection measures for combustible ultrafine particle processes and equipment.

25.9.4.20.5 Ultrafine Particle Production Processes.

25.9.4.20.5.1* Fire, flash fire, and explosion hazards associated with production of ultrafine particles shall be assessed and documented.

25.9.4.20.5.2 Any process that involves metal ultrafine particles shall refer to Chapter 22.

25.9.4.20.6 Housekeeping.

25.9.4.20.6.1 A documented housekeeping program shall be established based on the hazards documented in the DHA for all ultrafine particles and shall include special provisions for preventing personnel exposure to ultrafine particles during the cleaning process.

25.9.4.20.6.2 Personal protective equipment (PPE) provided for personnel during the cleaning process shall consider the hazards associated with the ultrafine particles involved.

25.9.5 Dust Control.

25.9.5.1 Housekeeping procedures shall be in accordance with Section 8.4 and 25.8.4.

25.9.5.2 Dust collection and centralized vacuum systems shall be designed in accordance with 9.4.3 and 25.9.4.3.

25.9.6 Ignition Source Control.

25.9.6.1 Reserved.

25.9.6.2 Reserved.

25.9.6.3 Reserved.

25.9.6.4* Bearings.

25.9.6.4.1 Roller or ball bearings shall be used on all processing and transfer equipment.

25.9.6.4.2 Bushings shall be permitted to be used when a documented engineering evaluation shows that mechanical loads and speeds preclude ignition due to frictional heating.

25.9.6.4.3 Lubrication shall be performed in accordance with the manufacturer's recommendations.

25.9.6.5 Reserved.

25.9.6.6 Electrostatic Discharges. For electrostatic hazard assessment purposes, MIE determination of dust clouds shall be based on a purely capacitive discharge circuit in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

25.9.6.6.1* Conductive Equipment.

25.9.6.6.2 Maximum Particulate Transport Rates.

25.9.6.6.2.1* The maximum particulate transport rates in 25.9.6.6.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft³ (1 m³) 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.

25.9.6.6.2.2* The maximum particulate transport rate in 25.9.6.6.2.3 shall apply when the volume of the vessel being filled is greater than 35 ft³ (1 m³) 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.

25.9.6.6.2.3* Where the conditions of 25.9.6.6.2.1 or 25.9.6.6.2.2 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).

25.9.6.6.3 Grounding of Personnel.

25.9.6.6.4 Flexible Intermediate Bulk Containers (FIBCs).

25.9.6.6.5* Where belt drives are used in areas where combustible dust clouds or ignitable vapor or gas atmospheres might be present, the belts shall have a resistance of less than 1.0×10^6 ohms to ground.

25.9.6.6.6* Where flexible hose is used to connect conductive components, the resistance between the conductive components shall be less than 1×10^6 ohms.

25.9.6.6.7 The requirements of 9.6.6.1, 25.9.6.6.1, 9.6.6.4, 25.9.6.6.4, 25.9.6.6.5, and 25.9.6.6.6 shall be applied retroactively.

25.9.6.6.8 Particulate solids shall not be manually dumped directly into vessels containing flammable atmospheres (gases at a flammable concentration with an oxidant) or where

displacement could cause a flammable atmosphere external to the vessel.

25.9.6.6.9* Manual additions of solids through an open port or a manway into a vessel containing flammable atmospheres shall be permitted to be done in 50 lb (25 kg) batches or smaller, provided the requirements of 25.9.6.6.9.1 through 25.9.6.6.9.7 are satisfied.

25.9.6.6.9.1* Conductive or static-dissipative components of the container shall be grounded.

25.9.6.6.9.2 Direct emptying of powders from nonconductive plastic bags into a vessel that contains a flammable atmosphere shall be strictly prohibited.

25.9.6.6.9.3 The use of nonconductive liners in grounded conductive or static-dissipative outer packaging shall be permitted, provided that the liner thickness is less than 0.08 in. (2 mm) and the liner cannot become detached during emptying.

25.9.6.6.9.4* Loading chutes, receiving vessels, and auxiliary devices used for addition of bulk material shall be conductive and grounded.

25.9.6.6.9.5* Personnel in the vicinity of openings of vessels that contain flammable atmospheres shall be grounded.

25.9.6.6.9.6 Operators shall wear flame-resistant garments as specified in NFPA 2113 and any other personal protective equipment (PPE) required for protection against flash fire hazards during charging operations.

25.9.6.6.9.7* A documented risk assessment acceptable to the AHJ shall be conducted to determine additional engineering and administrative controls necessary to protect against ignition of the flammable atmosphere.

25.9.6.7 Reserved.

25.9.6.8 Reserved.

25.9.6.9 Reserved.

25.9.6.10 Reserved.

25.9.6.11 Friction and Impact Sparks.

25.9.6.11.1 Floor sweepings shall not be returned to any machine.

25.9.6.11.2* Where the process is configured such that the pneumatic conveying, dust collection, or centralized vacuum cleaning system conveys materials that can act as an ignition source, means shall be provided to minimize the hazard.

25.9.6.11.3 The means used to minimize the ignition source hazard specified in 25.9.6.11.2 shall be permitted to include protection measures identified in Sections 9.2 and 9.9, as appropriate.

25.9.6.11.4* Belt drives shall be designed to stall without belt slippage, or a safety device shall be provided to shut down the equipment if slippage occurs.

25.9.6.11.5 Equipment with moving parts shall be installed and maintained so that true alignment is maintained and clearance is provided to minimize friction.

25.9.6.12 Reserved.**25.9.6.13 Reserved.****25.9.6.14 Electrical Systems.**

25.9.6.14.1 All electrical equipment and installations shall comply with the requirements of *NFPA 70*.

25.9.6.14.2* The identification of the possible presence and extent of hazardous (classified) locations shall be made based on the criteria in Article 500 or Article 506 of *NFPA 70*.

25.9.6.14.3 Hazardous (classified) locations that are identified in accordance with 25.9.6.14.2 shall be documented, and such documentation shall be permanently maintained on file for the life of the facility.

25.9.6.15 Process and Comfort Heating Systems.

25.9.6.15.1* In areas processing combustible dust, process and comfort heating shall be provided by indirect means.

25.9.6.15.2 Fired equipment shall be located outdoors or in a separate dust-free room or building.

25.9.6.15.3 Air for combustion shall be taken from a clean outside source.

25.9.6.15.4 Comfort air systems for processing areas containing combustible dust shall not be recirculated.

25.9.6.15.5 Recirculating systems shall be permitted to be used provided that all of the following criteria are met:

- (1) Only fresh makeup air is heated.
- (2) The return air is filtered to prevent accumulations of dust in the recirculating system.
- (3) The exhaust flow is balanced with fresh air intake.

25.9.6.15.6 Comfort air shall not be permitted to flow from hazardous to nonhazardous areas.

25.9.6.16 Other Vehicles. Risk management controls shall be implemented to ensure the safe operation of vehicles not covered under *NFPA 505*, which could introduce ignition sources into classified areas. Such risk management controls include the application of hot work controls under *NFPA 51B*.

25.9.7 Reserved.**25.9.8 Explosion Prevention and Protection.****25.9.8.1 Reserved.****25.9.8.2 Equipment Protection.**

25.9.8.2.1 The design of explosion protection for equipment 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 pressure containment in accordance with *NFPA 69*
- (4) Deflagration suppression systems in accordance with *NFPA 69*
- (5)* Dilution with a noncombustible dust to render the mixture noncombustible (*See 25.9.8.2.3.*)
- (6)* Deflagration venting through a listed dust retention and flame-arresting device

25.9.8.2.2* If the method in 25.9.8.2.1(1) is used, where the chemical properties of the material being conveyed require a minimum concentration of oxygen to control pyrophoricity or reactivity, that level of concentration shall be maintained.

25.9.8.2.3 If the method in 25.9.8.2.1(5) is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the AHJ.

25.9.8.3* Equipment Isolation.**25.9.9 Reserved.****25.9.10 Process and Facility Design.**

25.9.10.1 The design of processes and facilities that handle combustible particulate solids shall consider the physical and chemical properties that establish the hazardous characteristics of the materials.

25.9.10.2* The design and its basis shall be documented and maintained for the life of the process.

25.10 Reserved.

Annex A Explanatory Material

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

A.1.1 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 μm . *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.

A.1.3 The following is a suggested procedure for determining the requirements for a piece of equipment, building, or facility following the flow chart in Figure 1.3.2:

- (1) Refer to the fundamental chapters (Chapters 4 through 10) for requirements that apply to all of the industries or commodities covered by NFPA 660 [unless otherwise addressed in the specific chapter as noted in (2)]. This will include the following:
 - (a) Determining the combustibility hazards by following Chapter 5
 - (b) Performing a dust hazards analysis in accordance with Chapter 7
 - (c) Using the methods in Chapter 6 or Chapter 9 to manage the hazards
 - (d) Creating and implementing a hazard management plan in accordance with Chapter 8
- (2) Refer to the applicable industry- or commodity-specific chapter of the standard (Chapters 21 through 25) for additional requirements, prohibitions, or allowances specific to that industry or commodity. The scope of each chapter is located in __.1.1. The standard has been arranged so that requirements under a certain heading can be compared to requirements under that same heading in the industry- or commodity-specific chapters.
- (3) Where a conflict exists between the fundamental chapters and the industry- or commodity-specific chapters, refer to the conflicts section (Section 1.6) to resolve.

Some industry- or commodity-specific topics are not addressed in the fundamental chapters (Chapters 4 through 10). These are located in __.10 and beyond. Examples are thermal oil heating systems covered in Section 24.11 and handling of liquid sulfur covered in Sections 23.11 and 23.12.

Table A.1.3 guides the user to the appropriate sections of the standard for specific requirements.

For example, requirements for air-material separators (AMS) are located in 9.4.4, where Chapter 9 is the fundamental chapter addressing hazard management, and also the __.9.4.4 subsection of the applicable industry- or commodity-specific chapter.

To determine the requirements for an AMS in an agricultural dust facility, the user first refers to 9.4.4, AMS, to determine the fundamental requirements and then refers to Chapter 21, Agricultural and Food Processing, 21.9.4.4 to

review any additional requirements, prohibitions, or allowances specific to agricultural dusts. For AMS locations, the user would check 9.4.4.5, AMS Locations, for fundamentals and 21.9.4.4.5 for specifics.

Similarly, if evaluating pneumatic conveying systems for metal dust, the user first refers to 9.4.3, Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems, and 9.4.3.2, Specific Requirements for Pneumatic Conveying Systems, for fundamental requirements. Then, the user refers to Chapter 22, Combustible Metals, and refers to 22.9.4.3 and 22.9.4.3.2 to review any additional requirements, prohibitions, or allowances specific to metal dusts.

The user of NFPA 660 should always check for fundamental requirements in the fundamental chapters when using the industry- or commodity-specific chapters. Chapter 25 does not contain a section on dry AMS in 25.9.4.4.2, but that does not mean there are no requirements for them — rather 9.4.4.2 applies.

Even when there are not industry-specific requirements, the committee might provide extra annex material specific to their industry or commodity. For example, 24.9.3.4, Construction Features to Limit Accumulation, for wood dust does not add any additional requirements over those in fundamentals in 9.3.4, but annex material is provided in A.24.9.3.4 to explain methods of minimizing dust accumulation in inaccessible and elevated surfaces in woodworking facilities.

In some of the industry- or commodity-specific sections, the requirements supersede those in the fundamentals section. An example is the compressed air blowdown method requirements in 21.8.4.2.6 superseding those in 8.4.2.6.2. In other areas of the standard, the requirements are explicitly stated to apply in addition to those in the fundamentals section. In Chapter 22, Section 22.7 specifies that the hazards analysis requirements in Section 22.7 apply in addition to those in Chapter 7. If there is any conflict between the fundamentals section and the industry- or commodity-specific sections, then Section 1.6, Conflicts, should be used to determine which requirements apply.

Generally, the term *Reserved* is used to hold space and indicate to the user that the specified hazard is known and requires further analysis before potential requirements can be included in a future revision of the standard. While this meaning is also true for Chapters 4-10 in this standard, the use of the term *Reserved* in Chapters 21-25 generally means that space is held to align the section numbers with the fundamental sections in Chapters 4-10. Where *Reserved* is used in Chapters 21-25, the user should refer back to Chapters 4-10 for applicable requirements. For example, 9.8.1 for Explosion Protection and Prevention provides fundamental requirements for dust explosion hazards in enclosures. Because this a fundamental requirement, 22.9.8.1, 23.9.8.1, 24.9.8.1, and 25.9.8.1 all chose to use the term *Reserved* rather than provide specific requirements for dust explosion hazards in enclosures. However, 21.9.8.1 prescribes a requirement that is unique to agricultural facilities and therefore does not use the term *Reserved*. Despite its dual meaning, the term *Reserved* was chosen to be used rather than *Held for Alignment*, *Refer to Chapter/Section*, or similar terms because additional requirements for specific industries could be added in the future.

Current subsections of industry- and commodity-specific chapters above X.10 do not have corresponding fundamental

requirements. To avoid conflicts between these subsection numbers and the industry- and commodity-specific chapter numbers, Chapters 11 through 20 have been reserved.

A.1.3.2 This annex section provides a simple example of how to use NFPA 660 for modification of a dust collection system in a grain handling process, showing how Chapters 1 through 10 interface with Chapters 21 through 25. It is not intended to cover all the sections a user must review for their process and projects. There are several general requirements that need to be reviewed as well as Chapter 8, Management Systems.

It is assumed that the dust characteristics are understood and that the dust is combustible.

There are mainly three chapters associated with a change to a dust collection system for a grain handling process: Chapters 7, 9, and 21. See Table A.1.3.2.

If the example were in a wood processing facility, then the user would review Chapters 7, 9, and 24.

Chapter 7 has requirements for completing a dust hazards analysis (DHA) on the dust collection system. The corresponding Section X.7 of Chapter 21 (i.e., Section 21.7) should also be reviewed for additional and/or alternate requirements for DHAs for agricultural and food processing facilities.

Looking to Chapter 9, there is Section 9.4, Equipment Design. Within this section is 9.4.3.3, Specific Requirements for Dust Collection Systems [see Figure A.1.3.2(a)]. This section has a list of requirements for the dust collection system.

After reviewing 9.4.3.3, 21.9.4.3.3 should be reviewed for the following [see Figure A.1.3.2(b)]:

- (1) The section numbers and section headings have been aligned to make it easier to compare requirements from any section in Chapters 1 through 10 with the associated requirements in the industry- and commodity-specific chapters, 21 through 25.
- (2) When the heading says *Reserved* (such as 21.9.4.1), that means there are no additional requirements in this chapter and the user should simply follow 9.4.1.
- (3) If there is a heading (such as 21.9.4.3.3), then this chapter contains additional or alternative requirements to those listed in 9.4.3.3.

Section 9.4, Equipment Design, should then be reviewed for additional requirements for dust collection systems such as the following [see Figure A.1.3.2(c)]:

- (1) Note the sections for air material separators (AMS), air-moving devices (fans and blowers), duct systems, sight glasses, abort gates, and so forth.
- (2) Remember to always check Chapter 21 for requirements for those associated sections, looking for the matching section numbers and section headings.

Chapters 9 and 21 should also be reviewed for the requirements involving explosion prevention and protection for the dust collector [see Figure A.1.3.2(d)].

A.1.3.4 Ignitable fibers/flyings, as defined in NFPA 70 and NFPA 499, are not included in the definition of *combustible dust* in NFPA 70 and NFPA 499. NFPA 70 and NFPA 499 consider ignitable fibers/flyings to only be a fire hazard, so locations are classified differently, and the electrical installation includes additional restrictions compared to combustible fibers/flyings.

Table A.1.3 Organization of Fundamental Chapters and Industry- or Commodity-Specific Chapters

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
Chapter 1	Administration	__1
1.1	Scope	__1.1
1.2	Purpose	__1.2
1.3	Application	__1.3
1.4	Retroactivity	__1.4
1.5	Equivalency	__1.5
1.6	Conflicts	__1.6
1.7	Units and Formulas	__1.7
Chapter 4	General Requirements	__4
4.1	General	__4.1
4.2	Objectives	__4.2
4.2.1	Life Safety	__4.2.1
4.2.2	Mission Continuity	__4.2.2
4.2.3	Mitigation of Fire Spread, Explosions, or Releases of Hazardous Materials	__4.2.3
4.2.4	Compliance Options	__4.2.4
Chapter 5	Hazard Identification	__5
5.1	Responsibility	__5.1
5.2	Screening for Combustibility or Explosibility	__5.2
5.3	Self-Heating and Reactivity Hazards	__5.3
5.3.1	Self-Heating Hazard Evaluations	__5.3.1
5.3.2	Thermal Instability Hazard Evaluations	__5.3.2
5.3.3	Water Reactivity Hazard Evaluations	__5.3.3
5.3.4	Chemical Reactivity Hazard Evaluations	__5.3.4
5.4	Combustibility and Explosibility Tests	__5.4
5.4.1	Determination of Combustibility (Fire Hazard Potential)	__5.4.1
5.4.2	Determination of Flash Fire Potential	__5.4.2
5.4.3	Determination of Explosibility	__5.4.3

(continues)

Table A.1.3 *Continued*

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
5.4.4	Quantification of Combustibility and Explosibility Characteristics	__5.4.4
5.5	Sampling	__5.5
5.5.1	Sampling Plan	__5.5.1
5.5.2	Mixtures	__5.5.2
5.5.3	Representative Samples	__5.5.3
5.5.4	Sample Collection	__5.5.4
	Organometallic materials	__5.6
Chapter 6	Performance-Based Design Option	__6
6.1	General Requirements	__6.1
6.1.1	Retained Prescriptive Requirements	__6.1.1
6.1.2		__6.1.2
6.1.3	Approved Qualifications	__6.1.3
6.1.4	Document Requirements	__6.1.4
6.1.5	Re-evaluation	__6.1.5
6.1.6	Sources of Data	__6.1.6
6.1.7	Maintenance of the Design Features	__6.1.7
	Independent Review	__6.1.8
6.2	Risk Component and Acceptability	__6.2
6.3	Performance Criteria	__6.3
6.3.1	Life Safety	__6.3.1
6.3.2	Structural Integrity	__6.3.2
6.3.3	Mission Continuity	__6.3.3
6.3.4	Mitigation Fire Spread, Explosions, or Releases of Hazardous Materials	__6.3.4
6.3.5	Effects of Explosions	__6.3.5
	Effects of Deflagrations	__6.3.6
	Prevention of Ignition	__6.3.7
6.4	Design Scenarios	__6.4
6.4.1	Fire Scenarios	__6.4.1
6.4.2	Flash Fire and Explosion Scenarios	__6.4.2
6.5	Evaluation of Proposed Design	__6.5

(continues)

Table A.1.3 *Continued*

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
Chapter 7	Dust Hazards Analysis (DHA)	__7
7.1	General Requirements	__7.1
7.1.1	Retroactivity	__7.1.1
7.2	Criteria	__7.2
7.2.1	Overview	__7.2.1
7.2.2	Qualifications	__7.2.2
7.2.3	Documentation	__7.2.3
7.3	Methodology	__7.3
7.3.1	General	__7.3.1
7.3.2	Material Evaluation	__7.3.2
7.3.3	Process Systems	__7.3.3
7.3.4	Building or Building Compartments	__7.3.4
	Layer Depth Criterion Method	__7.3.5
	Mass Method A	__7.3.6
	Mass Method B	__7.3.7
	Risk Assessment Method	__7.3.8
	Molten metal hazards analysis criteria	__7.4
	Molten metal hazards analysis Methodology	__7.5
	Risk Evaluation	__7.6
	Dust Explosion and Flash Fire Hazard Areas	__7.7
Chapter 8	Management Systems	__8
8.1	Retroactivity	__8.1
8.2	General	__8.2
8.3	Operating Procedures and Practices	__8.3
8.3.3	Portable Appliances	__8.3.3
8.4	Housekeeping	__8.4
8.4.1	General	__8.4.1
8.4.2	Methodology	__8.4.2
8.4.2.1	Procedure	__8.4.2.1
8.4.2.2	Vacuum Cleaning Method	__8.4.2.2
8.4.2.2.1	Portable Vacuum Cleaners	__8.4.2.2.1

(continues)

Table A.1.3 *Continued*

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
8.4.2.2.2	Centralized Vacuum Cleaning Systems	___8.4.2.2.2
8.4.2.3	Sweeping, Shoveling, Scoop, and Brush Cleaning Method	___8.4.2.3
8.4.2.4	Water Washdown Cleaning Method	___8.4.2.4
8.4.2.5	Water Foam Washdown Systems (Reserved)	___8.4.2.5
8.4.2.6	Compressed Air Blowdown Method	___8.4.2.6
8.4.2.7	Steam Blow Down Method (Reserved)	___8.4.2.7
8.4.3	Training	___8.4.3
8.4.4	Equipment (Reserved)	___8.4.4
8.4.5	Vacuum Trucks	___8.4.5
8.4.6	Frequency and Goal	___8.4.6
8.4.7	Auditing and Documentation	___8.4.7
8.5	Hot Work	___8.5
8.5.7	Use of Portable Equipment	___8.5.7
8.5.8	Propellant-Actuated Devices and Explosive-Actuated Devices	___8.5.8
8.6	Personal Protective Equipment (PPE)	___8.6
8.6.1	PPE Applicability	___8.6.1
8.6.2	Workplace Hazard Assessment	___8.6.2
8.6.3	Limitations of PPE Application (Flame-Resistant Garments)	___8.6.3
8.6.4	Limitations of PPE to Combustible Dust Flash Fires (Reserved)	___8.6.4
8.6.5	Face, Hands, and Footwear Protection (Reserved)	___8.6.5
	Primary PPE for molten metals	___8.6.6
	PPE for General Work Areas Near or Containing Combustible Metals	___8.6.7

(continues)

Table A.1.3 *Continued*

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
8.7	Inspection, Testing, and Maintenance	___8.7
	General Requirements	___8.7.1
	Specific Equipment Maintenance	___8.7.2
	Impairments of Fire Protection and Explosion Prevention Systems	___8.7.3
8.8	Training and Hazard Awareness	___8.8
8.9	Contractors	___8.9
8.9.3	Contractor Training	___8.9.3
8.10	Incident Investigation	___8.10
8.11	Management of Change	___8.11
8.12	Pre-Startup Safety Review	___8.12
8.13	Documentation Retention	___8.13
8.14	Management Systems Review	___8.14
8.15	Employee Participation	___8.15
	Warning Signs	___8.16
	Misc Storage in Grain-Handling Facilities	___8.17
Chapter 9	Hazard Management: Mitigation and Prevention	___9
9.1	Inherently Safer Designs	___9.1
9.2	Risk Assessment	___9.2
9.3	Building Design	___9.3
9.3.1	Construction	___9.3.1
9.3.2	Building or Building Compartment Protection	___9.3.2
9.3.3	Life Safety	___9.3.3
9.3.4	Construction Features to Limit Accumulation	___9.3.4
9.3.5	Separation of Hazard Areas from Other Hazard Areas and from Other Occupancies	___9.3.5
9.3.5.1	General	___9.3.5.1
9.3.5.2	Use of Segregation	___9.3.5.2
9.3.5.3	Use of Separation	___9.3.5.3

(continues)

Table A.1.3 *Continued*

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
9.3.5.4	Use of Detachment	__9.3.5.4
9.4	Equipment Design	__9.4
9.4.1	General	__9.4.1
9.4.2	Design for Dust Containment	__9.4.2
9.4.3	Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems	__9.4.3
9.4.3.1	General Requirements	__9.4.3.1
9.4.3.1.3	Systems That Convey Hybrid Mixtures	__9.4.3.1.3
9.4.3.1.4	Operations	__9.4.3.1.4
9.4.3.1.5	Airflow Control Valves	__9.4.3.1.5
9.4.3.2	Specific Requirements for Pneumatic Conveying Systems	__9.4.3.2
9.4.3.3	Specific Requirements for Dust Collection Systems	__9.4.3.3
9.4.3.4	Specific Requirements for Centralized Vacuum Cleaning Systems	__9.4.3.4
9.4.4	AMS	__9.4.4
9.4.4.1	General	__9.4.4.1
9.4.4.2	Dry AMS	__9.4.4.2
9.4.4.3	Wet AMS	__9.4.4.3
9.4.4.4	Enclosureless AMS	__9.4.4.4
9.4.4.5	AMS Locations	__9.4.4.5
9.4.4.6	AMS Clean Air Exhaust	__9.4.4.6
9.4.4.7	AMS Construction	__9.4.4.7
9.4.5	Air-Moving Devices (Fans and Blowers)	__9.4.5
9.4.6	Duct Systems	__9.4.6
9.4.6.4	Access Doors	__9.4.6.4
9.4.7	Sight Glasses	__9.4.7
9.4.8	Abort Gates	__9.4.8
9.4.8.1	Construction	__9.4.8.1
9.4.8.2	Local Reset	__9.4.8.2
9.4.8.3	Integrity of Actuation Circuits	__9.4.8.3
9.4.9	Bulk Storage Enclosures	__9.4.9

(continues)

Table A.1.3 *Continued*

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
9.4.9.1	General	__9.4.9.1
9.4.9.2	Construction	__9.4.9.2
9.4.9.3	Fixed Bulk Storage Location	__9.4.9.3
9.4.9.4	Interior Surfaces	__9.4.9.4
9.4.9.5	Access Doors and Access Openings	__9.4.9.5
	Explosion Hazards and Protection	__9.4.9.6
9.4.10	Size Reduction	__9.4.10
9.4.11	Particle Size Separation	__9.4.11
9.4.12	Pressure Protection Systems	__9.4.12
9.4.13	Mechanical Feeding Devices	__9.4.13
9.4.14	Bucket Elevators	__9.4.14
9.4.15	Conveyors and Spouts	__9.4.15
9.4.16	Mixers and Blenders	__9.4.16
9.4.17	Dryers	__9.4.17
9.4.18	Transfer Points (Reserved)	__9.4.18
9.5	Dust Control	__9.5
9.5.1	General	__9.5.1
9.5.2	Liquid Dust Suppression Methods for Dust Control	__9.5.2
9.5.3	Fans for Continuous Dust Control	__9.5.3
9.6	Ignition Source Control	__9.6
9.6.1	Retroactivity	__9.6.1
9.6.2	Hot Work	__9.6.2
9.6.3	Hot Surfaces	__9.6.3
9.6.4	Bearings	__9.6.4
9.6.5	Hazardous (Classified) Locations for Electrical Installations	__9.6.5
9.6.6	Electrostatic Discharges	__9.6.6
9.6.6.1	Conductive Equipment	__9.6.6.1
9.6.6.1.4	Flexible Connectors	__9.6.6.1.4
9.6.6.2	Maximum Particulate Transport Rates	__9.6.6.2
9.6.6.3	Grounding of Personnel	__9.6.6.3

(continues)

Table A.1.3 Continued

Fundamental Chapters	Subject/Title	Industry- or Commodity-Specific Chapters
9.6.6.4	Flexible Intermediate Bulk Containers (FIBCs)	__9.6.6.4
9.6.6.5	Rigid Intermediate Bulk Containers (RIBCs)	__9.6.6.5
9.6.7	Open Flames and Fuel-Fired Equipment	__9.6.7
9.6.8	Industrial Trucks	__9.6.8
9.6.9	Process Air and Media Temperatures	__9.6.9
9.6.10	Self-Heating	__9.6.10
9.6.11	Friction and Impact Sparks	__9.6.11
9.6.12	Lightning Protection	__9.6.12
9.6.13	Smoking and Vaping	__9.6.13
	Electrical Systems	__9.6.14
9.7	Pyrophoric Dusts (Reserved)	__9.7
9.8	Explosion Prevention and Protection	__9.8
9.8.1	General	__9.8.1
9.8.2	Equipment Protection	__9.8.2
9.8.3	Equipment Isolation	__9.8.3
9.9	Fire Protection	__9.9
9.9.1	General	__9.9.1
9.9.2	System Requirements	__9.9.2
9.9.3	Fire Extinguishers	__9.9.3
9.9.4	Hose, Standpipes, Hydrants, and Water Supply	__9.9.4
9.9.4.1	Standpipes and Hose	__9.9.4.1
9.9.4.2	Nozzles	__9.9.4.2
9.9.4.3	Water Supply	__9.9.4.3
9.9.5	Automatic Sprinklers	__9.9.5
9.9.6	Detection and Extinguishing Systems	__9.9.6
9.9.7	Fire Alarm Service	__9.9.7
Chapter 10	Emergency Planning and Response	__10
10.1	Retroactivity	__10.1
10.2	Emergency Response Plan	__10.2
10.3	Reserved	__10.3

Table A.1.3.2 NFPA 660 Chapter Structure

Chapter 1	Administration
Chapter 2	Referenced Publications
Chapter 3	Definitions
Chapter 4	General Requirements
Chapter 5	Hazard Identification
Chapter 6	Performance-Based Design Option
Chapter 7	Dust Hazards Analysis (DHA)
Chapter 8	Management Systems
Chapter 9	Hazard Management: Mitigation and Prevention
Chapter 10	Emergency Planning and Response
Chapter 21	Agricultural and Food Processing (former NFPA 61)
Chapter 22	Combustible Metals (former NFPA 484)
Chapter 23	Sulfur (former NFPA 655)
Chapter 24	Wood Processing and Woodworking Facilities (former NFPA 664)
Chapter 25	Combustible Dusts and Particulate Solids Not Otherwise Specified (former NFPA 654)

A.1.3.9(4) Warehousing includes the storage of bags, super-sacks, 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 It is not always possible or practical for existing facilities to be in compliance retroactively with the provisions of this standard on its effective date. When the AHJ agrees that the owner/operator requires additional time for conformance, a plan and given completion date should be developed and acceptable to the AHJ.

A.1.4.2 This standard is usually enforced under authorities established by state law. Under the state building code, the edition of the standard adopted by the state at the time of construction is applicable.

Under federal law, the enforcement organization is usually the Occupational Safety and Health Administration (OSHA). Under Section 5(a)(1) of the OSH Act, the current edition of a standard is typically referenced during an enforcement action.

For existing facilities, it is often impractical to retroactively apply new engineering controls upon issuance of a new standard. Where this is the case and the retroactivity clause allows an exemption from the standard's requirements, the facility owner should refer to the version of the standard that was in effect at the time the facility was constructed or at the time of the most recent major renovation. However, recognizing that the

Chapter 9 Hazard Management: Mitigation and Prevention			9.4.3.3* Specific Requirements for Dust Collection Systems.		
		9.1 Inherently Safer Designs. (Reserved)			9.4.3.3.1* At each collection point, the system shall be designed to achieve the minimum velocity required for capture, control, and containment of the dust source.
		9.2 Risk Assessment.			
		9.3 Building Design.			9.4.3.3.2* The hood or pickup point for each dust source shall have a documented minimum air volume flow based upon the system design.
		9.4 Equipment Design.			9.4.3.3.3* 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.
		9.4.1 General.			9.4.3.3.4* 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.
		9.4.2 Design for Dust Containment.			9.4.3.3.5* Dust collection systems that remove material from operations that could generate flames, sparks, or hot material under normal operation conditions shall provide a means to prevent propagation of these flames, sparks, or hot material to the AMS or creation of a fire or explosion hazard within the ductwork.
		9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.			
		9.4.3.1 General Requirements.			
		9.4.3.2 Specific Requirements for Pneumatic Conveying Systems.			
		9.4.3.3 Specific Requirements for Dust Collection Systems.			
		9.4.3.4 Specific Requirements for Centralized Vacuum Cleaning Systems.			

FIGURE A.1.3.2(a) Layout of Chapter 9 and 9.4.3.3.

9.4 Equipment Design.			21.9.4 Equipment Design.		
		9.4.1 General.			21.9.4.1 Reserved.
		9.4.2 Design for Dust Containment.			21.9.4.2 Reserved.
		9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.			21.9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.
		9.4.3.1 General Requirements.			21.9.4.3.1 General Requirements.
		9.4.3.2 Specific Requirements for Pneumatic Conveying Systems.			21.9.4.3.2 Reserved.
		9.4.3.3 Specific Requirements for Dust Collection Systems.			21.9.4.3.3 Specific Requirements for Dust Collection Systems.
		9.4.3.4 Specific Requirements for Centralized Vacuum Cleaning Systems.			21.9.4.3.4 Specific Requirements for Centralized Vacuum Cleaning Systems.

FIGURE A.1.3.2(b) Comparison Between Section 9.4 and 21.9.4.

current revision might correct deficiencies in prior editions, facility owners should review the risk associated with the facility and determine whether alternative means of protection are necessary to meet their risk tolerance and satisfy the AHJs.

A.1.6.2 Some industry- or commodity-specific chapters provide reduced requirements for facilities or operations below a threshold size or that handle combustible dust below a minimum quantity. For instance, 24.1.1.2 indicates that certain requirements do not apply to woodworking operations below a threshold size in area and dust collection flow rate, and 22.1.1.11 indicates that the document does not apply to facilities that handle combustible metal in quantities less than threshold quantities. It is not the intent of NFPA 660 to apply requirements to facilities that are similar to requirements from which they have been excluded in industry- or commodity-specific chapters due to the limited size of the facilities or operation or the quantities of materials handled.

A.1.7.1 Where extracted text contains values expressed in only one system of units, the values in the extracted text have been retained without conversion to preserve the values established by the responsible technical committee in the source document.

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 or 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 standards in a broad manner because 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

9.4 Equipment Design.		9.4.6 Duct Systems.	
	9.4.1 General.		9.4.6.1 Ducts that handle combustible particulate solids shall conform to the requirements of NFPA 91, except as amended by the requirements of this chapter.
	9.4.2 Design for Dust Containment.		9.4.6.2* 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.
	9.4.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.		9.4.6.3* When ducts pass through a physical barrier erected to segregate dust or particulate solid fire, flash fire, or explosion hazards, physical isolation protection shall be provided to prevent propagation of fire, flash fire, or explosions between segregated spaces.
	9.4.4 AMS.		9.4.6.4 Access Doors.
	9.4.5 Air-Moving Devices (Fans and Blowers).		9.4.6.4.1 Access doors, openings, or removable sections of ductwork shall be provided to allow inspection, cleaning, maintenance, and fire department access.
	9.4.6 Duct Systems.		9.4.6.4.2 Access doors, openings, or removable sections of ductwork shall be designed and maintained to prevent dust leaks and preserve the integrity of the duct.
	9.4.6.1		9.4.6.4.3 Access doors, openings, or removable sections of ductwork that are not specifically designed for deflagration venting shall not be considered as providing that function.
	9.4.6.2		9.4.6.4.4* Access doors, openings, or removable sections of ductwork shall be bonded and grounded.
	9.4.6.3		
	9.4.6.4 Access Doors.		
	9.4.7 Sight Glasses.		
	9.4.8 Abort Gates.		
	...		

FIGURE A.1.3.2(c) Additional Design Requirements.

Chapter 9 Hazard Management: Mitigation and Prevention		21.9 Hazard Management: Mitigation and Prevention.	
	9.1 Inherently Safer Designs. (Reserved)		21.9.1 Reserved.
	9.2 Risk Assessment.		21.9.2 Reserved.
	9.3 Building Design.		21.9.3 Building Design.
	9.4 Equipment Design.		21.9.4 Equipment Design.
	9.5 Dust Control.		21.9.5 Dust Control.
	9.6 Ignition Source Control.		21.9.6 Ignition Source Control.
	9.7 Pyroporic Dusts. (Reserved)		21.9.7 Reserved.
	9.8 Explosion Prevention and Protection.		21.9.8 Explosion Prevention and Protection.
	9.9 Fire Protection.		21.9.9 Fire Protection.

FIGURE A.1.3.2(d) Location of Requirements for Explosion Prevention and Protection.

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.3.3.1 Abort Gate. Abort gates are quick-acting, high-speed devices specially designed to divert flame and process material. They do not include diverters used in the process with metal detectors used to identify contamination for other purposes. Abort gates are not intended to be used as deflagration isolation devices. (CMD-FUN)

A.3.3.2 Additive Manufacturing (AM). Additive manufacturing is sometimes referred to as 3D printing; however, this is only one part of the process. (CMD-FUN)

A.3.3.3 Agricultural Combustible Dust. Typically, agricultural combustible dust is material 500 μm or smaller in diameter or 500 μm or smaller in one dimension that has a K_{St} less than 200, a minimum ignition energy (MIE) greater than 30 mJ, a P_{max} less than 10 bar, and a minimum explosible concentration (MEC) greater than 40 g/m³ when suspended or dispersed in air. Data for typical agricultural dust can be found in A.21.5. (CMD-AGR)

A.3.3.5 Air-Material Separator (AMS). Examples include cyclones, enclosureless dust collectors, point-of-use dust collectors, and bin vents.

An AMS technically could be an oversized section of ductwork (e.g., a drop-box).

Typically, an AMS used in a dust collection system will, in addition to separating the conveyed material from the air/gas stream, include the ability to collect the separated material within the AMS to allow for continuous discharge of that material.

(CMD-FUN)

A.3.3.5.1 Cyclone. A cyclonic separator (cyclone) is a device utilizing centrifugal forces and geometry to separate the majority particulates from the conveying air/gas. The efficiency of this separation is based upon many factors such as the geometry of the cyclone, material particle size distribution and density, and air/gas velocity. Generally, this unit is used as an initial or primary separator, and additional separation devices might be needed to meet air pollution control requirements. Specially designed cyclones are able to meet air pollution control requirements but require special engineering data and know-how to design.

Examples of cyclones are shown in Figure A.3.3.5.1(a) and Figure A.3.3.5.1(b).

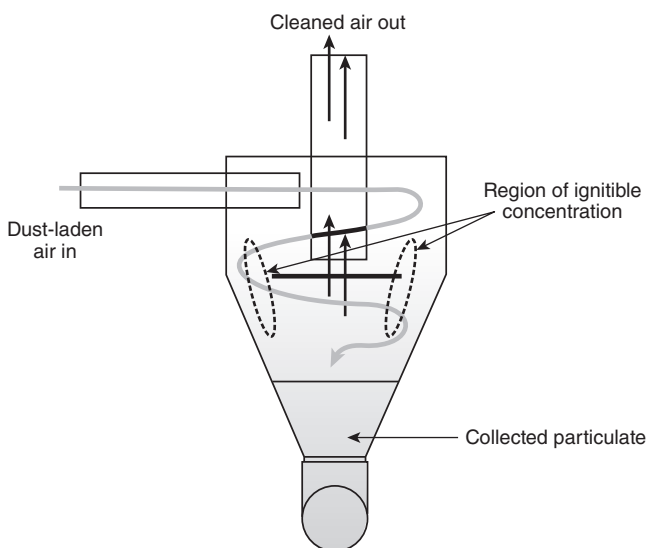


FIGURE A.3.3.5.1(a) Low to Medium Efficiency Cyclone.

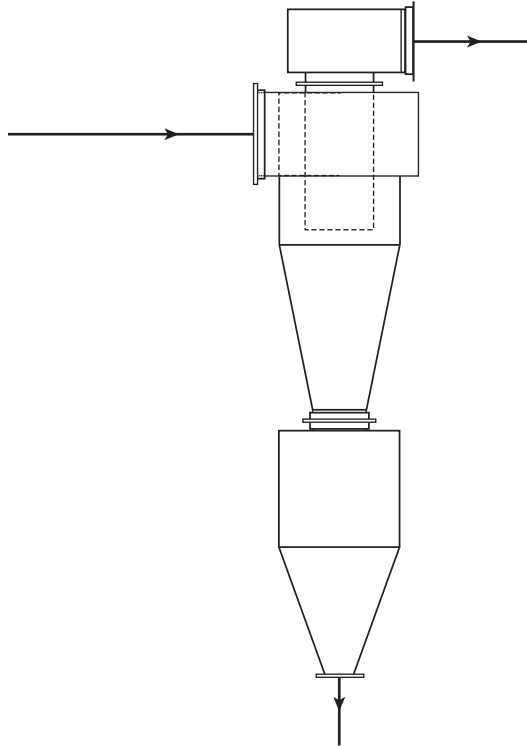


FIGURE A.3.3.5.1(b) High Efficiency Cyclone.

A.3.3.5.3 Dust Collector. Such devices often have automatic methods for continuous filter cleaning in order to maintain the operational efficiency of the device. Typically, the filter medium is either cartridges or bags over metal cages. The operating pressure of this device, especially if operating in a negative pressure (vacuum) condition, is usually limited by its shape and physical construction.

Examples of dust collectors are shown in Figure A.3.3.5.3(a) through Figure A.3.3.5.3(e).

(CMD-FUN)

A.3.3.5.4 Enclosureless AMS. An example of an enclosureless AMS is shown in Figure A.3.3.5.4.

A.3.3.5.5 Filter Receiver. A filter receiver is similar to a dust collector but can be designed for higher vacuum and pressure applications. Dust loading is often higher than a fugitive dust collection system since these units are typically used as an AMS for a product conveying system. (CMD-FUN)

A.3.3.5.9 Portable Vacuum Cleaner. A portable vacuum cleaner is any device that either allows the direct use of a hose (with or without tools) or is used to connect to a fixed-pipe run with hose connection stations. Such a device should have the following:

- (1) A method to separate the vacuumed material from the conveying air flow. This is typically either a filter or filters (depending upon size and air flow rate) or a wet separation (impact or partially submerged). It can also include a modified canister or enclosure of the separation media.
- (2) A device and/or method to provide conveying air flow at a sufficient vacuum level to allow use as a vacuum cleaner. This can range from a venturis connected to a

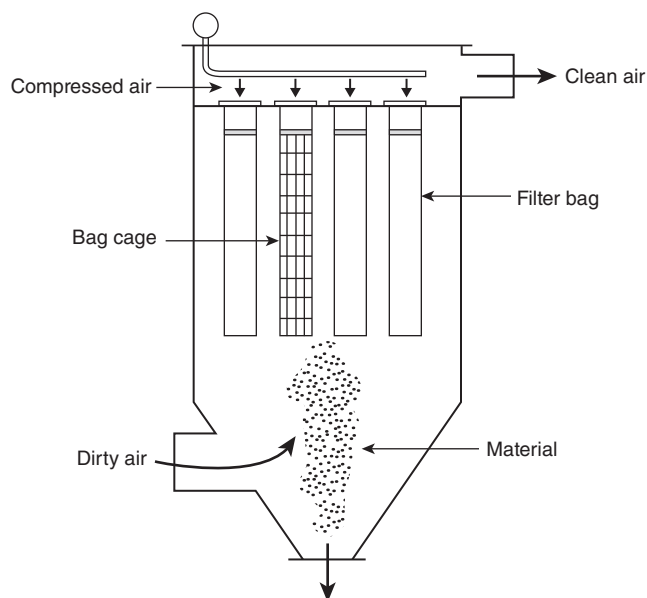


FIGURE A.3.3.5.3(a) Bag Collector with Compressed Air Cleaning.

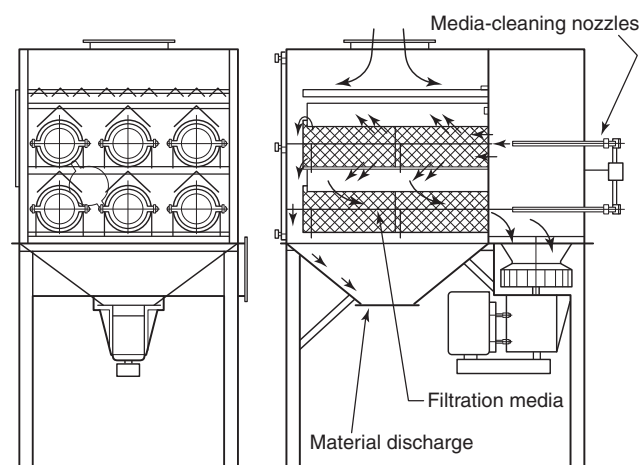


FIGURE A.3.3.5.3(b) Downflow Cartridge Collector with Compressed Air Cleaning.

compressed air supply to positive displacement, centrifugal, or regenerative vacuum blowers. Smaller units can use integral small vacuum blowers.

The assemblies can range from drum cover units to large assemblies that require a forklift to move from one location to another. Combustible dust hazards and risks must be considered when using these devices. Additional information is provided in Chapter 9. Examples of portable vacuum cleaners are shown in Figure A.3.3.5.9(a) and Figure A.3.3.5.9(b).

A.3.3.5.10 Wet Scrubber (Wet-Type AMS). A wet scrubber is a device utilizing geometry, physical barriers, and/or absorption methods, along with a fluid (e.g., sprays and streams) to separate and collect gases and/or dusts.

Examples of wet scrubbers are shown in Figure A.3.3.5.10(a) and Figure A.3.3.5.10(b). (CMD-FUN)

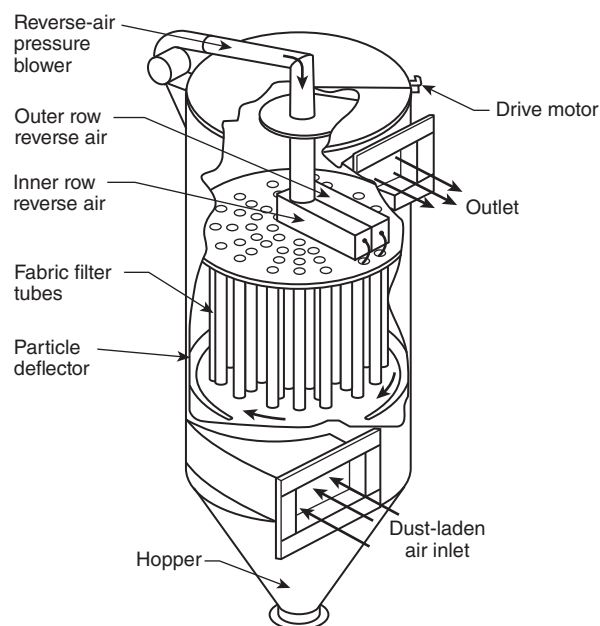


FIGURE A.3.3.5.3(c) Bag Collector with Dust Collecting on Outside of Bag and with High Pressure Cleaning (Reverse Air).

A.3.3.6 Air-Moving Device (AMD). An air-moving device is a fan or blower. A general description of each follows:

- (1) Fans
 - (a) Fans include 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) Blowers include 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.

(CMD-FUN)

A.3.3.10 Bulk Raw Grain. Examples include cereal grains, oilseeds, and legumes. Cleaning or drying does not constitute processing. (CMD-AGR)

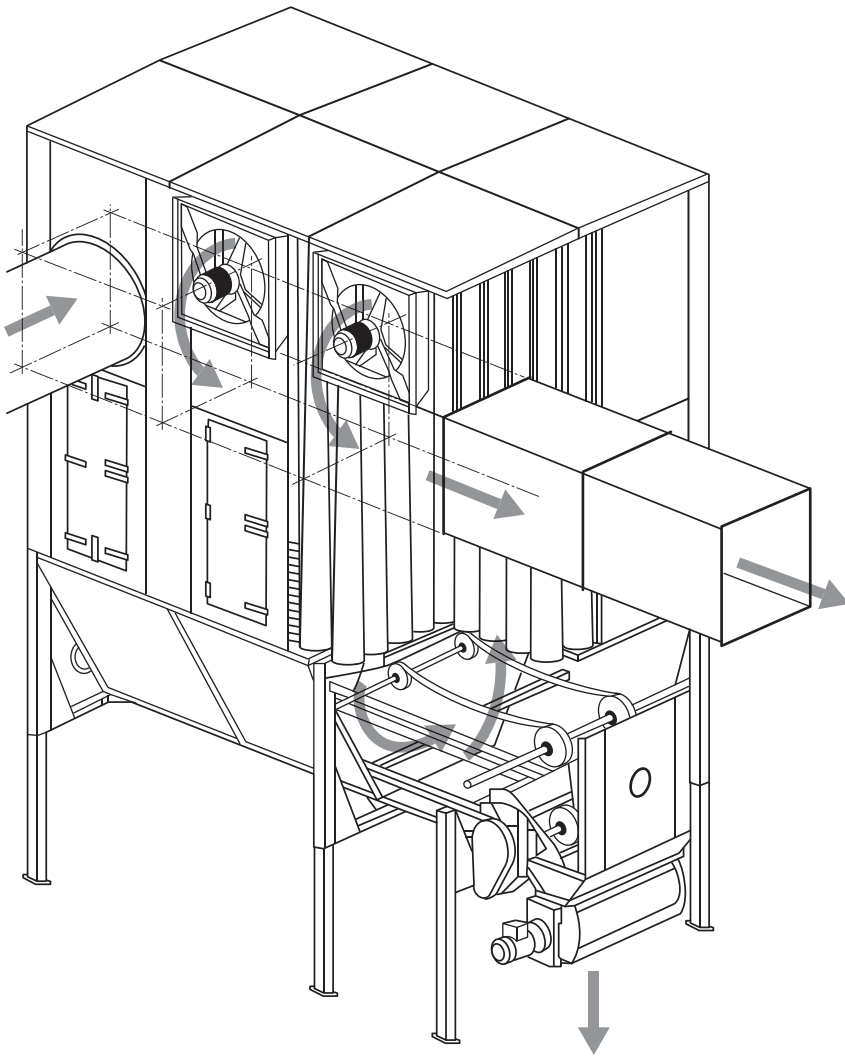


FIGURE A.3.3.5.3(d) Bag Collector with Dust Collecting on Inside of Bag and with Reverse Air Cleaning.

A.3.3.11.1 Heavy Casting (Metal). Castings less than 25 lb (11.3 kg) are considered light castings. (CMD-CMM)

A.3.3.12 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 or wet separator) can be used if large quantities of materials are involved. However, most filter receivers or wet separators are capable of handling the high material loadings without the use of a cyclone. (CMD-FUN)

A.3.3.13 Chips (Metal). Chips vary in ease of ignition and rapidity of burning, depending on their size and geometry. A light, fluffy chip can ignite easily and burn vigorously, whereas

a heavy, compact chip ignites with difficulty and burns quite slowly. (CMD-CMM)

A.3.3.14 Combustible Dust. The term *combustible dust* when used in this standard includes powders, fines, fibers, flyings, etc. Combustible fibers/flyings are specifically mentioned because, while the hazard is the same, *NFPA 70* and *NFPA 499* treat combustible dust and combustible fibers/flyings separately in regards to establishing hazardous (classified) locations and specifying the electrical installation. *NFPA 70* and *NFPA 499* do not consider ignitable fibers/flyings to be a flash fire or explosion hazard, and they are not specifically included in the definition of *combustible dust* in this standard. The difference between ignitable fibers/flyings and combustible fibers/flyings is the condition of being deposited in a layer that is not readily entrainable. A given material might be a combustible fiber/flying when suspended but become an ignitable fiber/flying when deposited in a layer. Ignitable fibers/flyings normally present a fire hazard, so locations are classified differently, and the electrical installation includes additional restrictions compared to combustible fibers/flyings. However, some

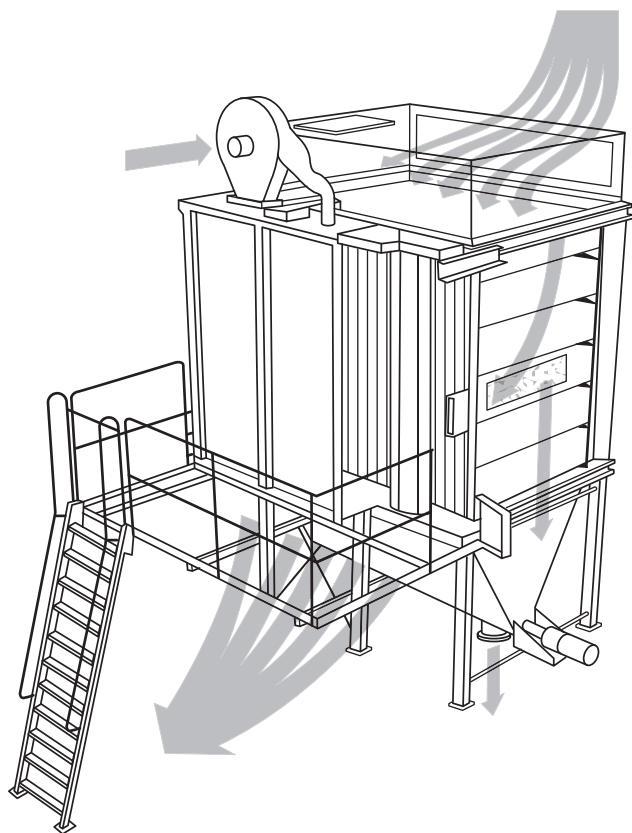


FIGURE A.3.3.5.3(e) Envelope Bag Collector with Reverse Air Cleaning.

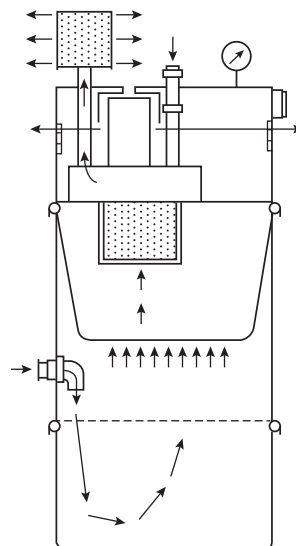


FIGURE A.3.3.5.9(a) Portable Vacuum Cleaner with Built-In Vacuum Source (AMD).

ignitable fibers/flyings could present a flash fire or explosion hazard if suspended and could pose similar hazards as combustible dust.

This definition also includes consideration of a process-specific oxidizing medium other than air. A larger particle size material might not present a hazard in air, yet could present a hazard in an atmosphere with increased oxygen concentration. Similarly, a combustible metal might still present a hazard in an atmosphere typically considered inert, such as CO₂ or nitrogen.

Dusts traditionally were defined as material 420 µm or smaller (i.e., capable of passing through a US No. 40 standard sieve). For consistency with other standards, 500 µm (i.e., capable of passing through a US 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 the smallest

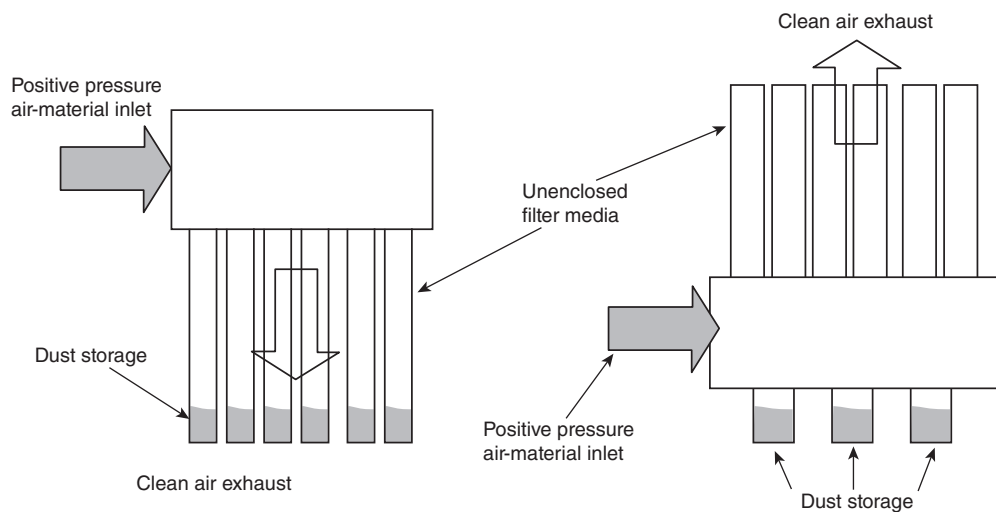


FIGURE A.3.3.5.4 Enclosureless Dust Collector.

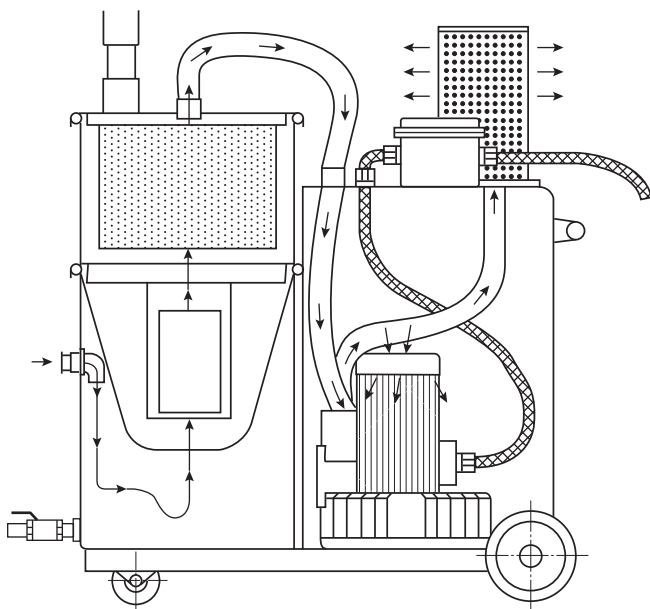


FIGURE A.3.3.5.9(b) Portable Vacuum Cleaner with Separate Vacuum Source (AMD).

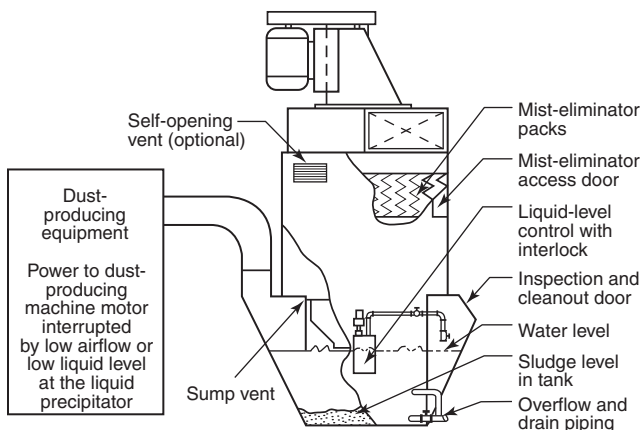


FIGURE A.3.3.5.10(a) Scrubber with Internal Baffles and Water Sump.

dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a flash fire or explosion hazard. Fibers/flyings with lengths that are large compared to their diameter or thickness usually do not pass through a 500 μm sieve, yet could still pose a flash fire or explosion 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 combustible particulate solid that has the smallest 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 smallest 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

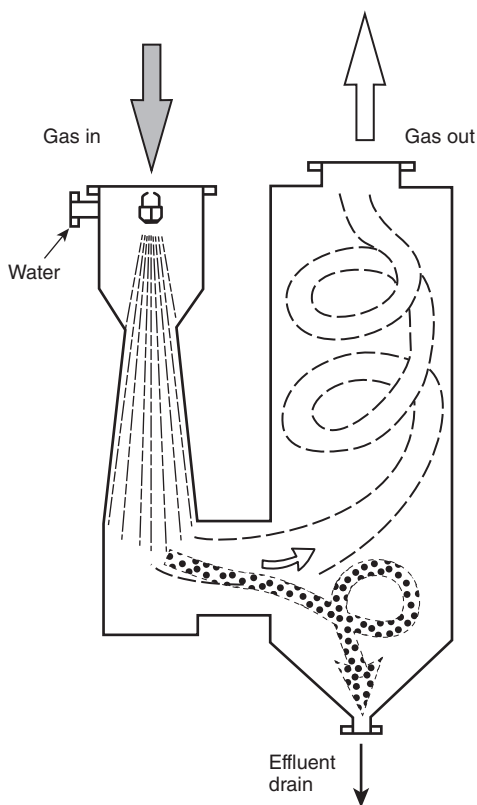


FIGURE A.3.3.5.10(b) Venturi-Style Scrubber.

screening test methodology such as provided in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, 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 (5.3 gal) 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 [$\geq 1 \text{ m}^3$ ($\geq 35.3 \text{ ft}^3$)] 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 (5.3 gal) chamber due to the use of strong pyrotechnic igniters. The activation of the pyrotechnic igniters increases both the initial pressure and temperature in the 20 L (5.3 gal) sphere by significant amount prior to the combustion of the dust itself [Taveau, J., et al]. These new pre-existing conditions might or might not physically alter the dust being tested, depending on its physical properties. For material with low flash point, the conjectured mechanism is that the pyrotechnic igniters are able to induce sufficient sublimation and vapor formation to change the combustion mechanism scenario from combustion of solid particles (i.e., dust) to combustion of a mixture of particles and a flammable gas (or

vapor). Authors of “Igniter-induced hybrids in the 20-L sphere,” in the *Journal of Loss Prevention in the Process Industries* [Taveau, J., et al.] proposed to call this phenomenon an *igniter-induced hybrid*. Whereas in a 1 m³ (35.3 ft³) chamber the effect disappears after the initial kernel propagates, in a 20 L (5.3 gal) sphere these effects persist throughout the flame propagation, leading to an increased reactivity of the tested material. Authors of Taveau, J., et al expect that the probability of an igniter-induced hybrid increases as the flash point and/or the MAIT of the powder in question decreases. For that reason, the reference method for explosibility testing is based on a 1 m³ (35.3 ft³) chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m³ (35.3 ft³) chamber for most dusts.

NFPA 68 also recognizes this problem and addresses it stating that “the 20 L test apparatus is designed to simulate results of the 1 m³ chamber; however, the igniter discharge makes it problematic to determine K_{St} values less than 50 bar-m/sec. Where the material is expected to yield K_{St} values less than 50 bar-m/sec, testing in a 1 m³ chamber might yield lower values.”

Any time a combustible dust is processed or handled, a potential for a flash fire or explosion exists. The degree of flash fire or explosion hazard varies, depending on the type of combustible dust and the processing methods used.

Refer to A.7.2.1 for a description of the conditions required for a combustible dust flash fire or explosion to occur.

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 flash fire and explosion hazards 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
- (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 characteristics 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.

The definition of *combustible dust* focuses on flash fire and explosion hazards, but fires in piles or layers of combustible particulate solids are also a concern that is addressed in this standard. A combustible dust that poses a flash fire or explosion hazard could also pose a fire hazard when in the form of a

settled accumulation. This can also be the case for combustible particulate solids with a minimum dimension greater than 500 μm . (CMD-FUN)

A.3.3.15 Combustible Metal. See A.22.1.1.3 for further information on determining the characteristics of metals. (CMD-FUN)

A.3.3.15.1 Combustible Metal Dust. Dust from some processes can contain various amounts or concentrations of organic material. The burning characteristics from the mixture as determined from testing are used to distinguish between a combustible metal dust and a combustible dust. (CMD-CMM)

A.3.3.15.3 Metal Dust. Dust from some processes could contain various amounts or concentrations of organic material. The burning characteristics from the mixture as determined from testing are used to distinguish between a combustible metal dust and a combustible dust. (CMD-CMM)

A.3.3.16 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 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 flash fire or explosion 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 US No. 40 standard sieve). For consistency with other standards, 500 μm (capable of passing through a US No. 35 standard sieve) is now consid-

ered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with the smallest dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a flash fire or explosion hazard. Fibers/flyings with lengths that are large compared to their diameters usually do not pass through a 500 μm sieve, yet could still pose a flash fire or explosion 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 the smallest 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 smallest 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 *finer* 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 flash fire or explosion 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 explosibility properties (higher K_{st} , lower MIE, etc.).

For purposes of determining appropriate electrical installation requirements for combustible particulate solids, NFPA 499 has defined three material subgroups that can warrant establishing hazardous (classified) locations. Combustible dusts, per NFPA 499, are materials with a particle size less than 500 μm that can propagate a deflagration when suspended in a cloud, as determined by test. Combustible fibers/flyings are larger than 500 μm in at least one dimension, yet can still propagate a deflagration in a cloud. Both of these first two subgroups present flash fire or explosion hazards when suspended in a cloud, as well as fire hazards when in a layer. Ignitable fibers/flyings are larger than 500 μm in at least one dimension, but either are too large or too agglomerated to suspend in the typical test or do not propagate a deflagration in a cloud. Ignitable fibers/flyings do not present a flash fire or explosion hazard, yet still present a fire hazard when in a layer. All three of these subgroups defined in NFPA 499 are included in the term *combustible particulate solid* as defined and used in this standard. Combustible fibers/flyings as defined in NFPA 499 are included in the term *combustible dust* as used and defined in this standard.

NFPA 70 provides different installation requirements for each of these three material subgroups. Materials smaller than 500 μm require more stringent dust exclusion designs (i.e., Class II or Zone Group IIIB) than materials larger than 500 μm (i.e., Class III or Zone Group IIIA). The exception to this is combustible metals, where both combustible metal dust and combustible metal fibers/flyings require Class II or Zone Group IIIC installations. Ignitable fibers/flyings additionally require lower maximum surface temperatures than combustible fibers/flyings for certain electrical equipment subject to overload conditions. When a hazardous (classified) location is established to address the presence of more than one of the three subgroups, the more stringent electrical installation requirements should be applied. (CMD-FUN)

A.3.3.21 Conductive. A typical threshold for solid materials would be a volume resistivity less than 10^5 ohm-m. (CMD-FUN)

A.3.3.23 Critical Process. The following are examples of critical processes, but the list is not all-inclusive:

- (1) Any operation such as mixing or screening of tantalum powder that results in a dust cloud
- (2) A process that raises tantalum to an elevated temperature, where a failure could cause the tantalum to be exposed to a source of oxygen (including atmospheric air)
- (3) A furnace or passivation process that could result in a fire or explosion if a catastrophic failure allowed the tantalum to be exposed to a source of oxygen
- (4) A furnace or other equipment that contains tantalum at temperatures sufficient to cause auto-ignition if not cooled over a period of time

(CMD-CMM)

A.3.3.24 Damage-Limiting Construction. This construction method usually makes maximum use of exterior walls as pressure-relieving walls rather than relying on the minimum recommended. Pressure-resistive walls are sometimes included to help prevent explosion propagation into adjacent areas. Further information on this subject can be found in NFPA 68. (CMD-FUN)

A.3.3.25 Deflagration. This document provides guidance for preventing or mitigating the effects of three types of events: settled solids fires, flash fires in suspended clouds of dusts, and explosions. The latter two events are produced when the fuel is suspended in the oxidizing medium, resulting in a propagating flame front (fireball) and, if confined, a pressure increase that can cause personnel injuries or the rupture of process equipment or buildings.

In this context of this document, the term deflagration refers only to combustion events involving suspended clouds of dusts — that is, flash fires and explosions. (CMD-FUN)

A.3.3.26 Deflagration Hazard. A hazard is usually determined to exist where either of the two following conditions is present:

- (1) Deflagrable dust is present as a layer on upward-facing surfaces at a depth greater than that permitted in Chapters 21, 22, 25, 23, and 24.
- (2) Deflagrable dust is suspended in the air at a concentration in excess of 25 percent of the MEC under normal operating conditions.

Since a deflagration is a rapid propagation of a flame front through a fuel-air mixture, a deflagration can result in widespread ignition of combustibles, thermal burns to occupants, and severe structural damage to the building, including fire and building collapse. (CMD-FUN)

A.3.3.27.1 Dust Explosion Hazard Area. A dust explosion hazard requires that a dust deflagration be confined within an enclosure providing for the accumulation of a damaging level of pressure. See NFPA 68 for evaluating strength of enclosures. (CMD-FUN)

A.3.3.27.2 Dust Flash Fire Hazard Area. A propagating deflagration yields a flash fire through the hazard area. Where the dust cloud concentration is equal to or greater than the MEC, it poses a dust explosion and dust flash fire hazard. In *Dust Explosions in the Process Industries*, Eckhoff observes for coal dust that if the cloud obscures a 25 W lightbulb over a 6.6 ft (2 m)

length, the concentration is probably close to the MEC. It is recognized that it is often very difficult or impractical to measure airborne dust concentration in this range in an industrial setting. For this reason, it is often necessary to rely on subjective measures to determine the dust cloud concentration. To apply a degree of conservatism, it is customary to consider a dust cloud hazardous when the concentration exceeds 25 percent of the MEC. (CMD-FUN)

A.3.3.30 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. (CMD-FUN)

A.3.3.33 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, and so forth, used to provide the controlled pathway from the hoods to the dust collector (AMS). Maintaining adequate duct velocity [usually 4000 ft/min (20.3 m/sec) 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. (CMD-FUN)

A.3.3.34 Dust Explosion Hazard. A dust explosion hazard requires that a dust deflagration be confined within an enclosure providing for the accumulation of a damaging level of pressure. An explosion hazard can exist in an enclosure of any type, including but not limited to silos, dust collectors, enclosed conveyors, bins, bunkers, rooms, and buildings. (CMD-FUN)

A.3.3.35 Dust Hazards Analysis (DHA). In the context of this definition, it is not intended that the 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. (CMD-FUN)

A.3.3.36 Enclosure. Examples of enclosures include a room, building, vessel, silo, bin, pipe, or duct. [68, 2023] (CMD-FUN)

A.3.3.38 Explosible. For dusts, explosibility is determined as described in 5.4.3. For hybrid mixtures, see NFPA 68. (CMD-FUN)

A.3.3.40 Explosive-Actuated Device. Explosive-actuated devices are also termed *powder-actuated devices*. US Army Corp of Engineers 13.e.01 equates these two terms and requires both to be designed in accordance with ANSI/ASSP A10.3, *Safety Requirements for Powder-Actuated Fastening Systems*. (CMD-FUN)

A.3.3.41.1 Combustible Fibers/Flyings. Section 500.5 of *NFPA 70* defines a Class III location. Combustible fibers/flyings can be similar in physical form to ignitable fibers/flyings and protected using the same electrical equipment installation methods. Examples of fibers/flyings include flat platelet-shaped particulate, such as metal flake, and fibrous particulate, such as particle board core material. If the smallest dimension of a combustible material is greater than 500 μm , it is unlikely that the material would be combustible fibers/flyings, as determined by test. Finely divided solids with lengths that are large compared to their diameter or thickness usually do not pass through a 500 μm sieve, yet when tested could potentially be determined to be explosible. [499, 2024]

The typical test methods for evaluating an explosible mixture are ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, ISO 6184-1, *Explosion protection systems — Part 1: Determination of explosion indices of combustible dusts in air*, or ISO/IEC/UL 80079-20-2, *Explosive atmospheres — Part 20-2: Material characteristics — Combustible dusts test methods*, for procedures for determining the explosibility of dusts. A material that is found to not present an explosible mixture could still be an ignitable fiber/flying, as defined in 3.3.41.2. Historically, the explosibility condition has been described as presenting a flash fire or explosion hazard. It could be understood that the potential hazard due to the formation of an explosible mixture when suspended in air at standard atmospheric pressure and temperature would include ignition. [499, 2024]

While this standard includes larger yet still hazardous materials as a subset of combustible dust, *NFPA 70* addresses them separately for purposes of defining the appropriate electrical classification. Although the hazard is the same when dispersed in a cloud, the electrical installation to prevent ingress of combustible fibers/flyings is different. (CMD-FUN)

A.3.3.41.2 Ignitable Fibers/Flyings. Section 500.5 of *NFPA 70* defines a Class III location as one where ignitable fibers/flyings are present, but not likely to be in suspension in the air in quantities sufficient to produce ignitable mixtures. This description addresses fibers/flyings that do not present a flash fire hazard or explosion hazard by test. This could be because those fibers/flyings are too large or too agglomerated to be suspended in air in sufficient concentration, or at all, under typical test conditions. Alternatively, this could be because they burn so slowly that, when suspended in air, they do not propagate combustion at any concentration. [499, 2024]

In this document the zone classification system includes ignitable fibers/flyings as a fire hazard in a layer, which is not addressed in the IEC zone system (see IEC 60079-10-2, *Explosive atmospheres — Part 10-2: Classification of areas — Explosive dust atmospheres*). Where these are present, the user could also

consider installation in accordance with Article 503 of NFPA 70. [499, 2024]

Where a process-specific oxidizing medium or elevated temperature process is present, ignitable fibers can produce a flash fire or explosion hazard. (CMD-FUN)

A.3.3.43 Fire Hazard. In the context of this standard, the term *fire*, absent a modifier such as *flash fire*, is intended to refer to the combustion of settled layers or piles of combustible particulate solids. (CMD-FUN)

A.3.3.44 Fire-Resistive. The requirements are described in NFPA 220. (CMD-FUN)

A.3.3.45 Flame Resistance. Flame resistance can be an inherent property of a material, or it can be imparted by specific treatment. [2113, 2025] (CMD-FUN)

A.3.3.47 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. Flash fires can also involve hybrid mixtures. 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. Refer to A.7.2.1 for a description of the conditions required for a combustible dust flash fire to occur. (CMD-FUN)

A.3.3.48 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., metal dust) having a concentration sufficient to allow flame propagation. Flammable gas, flammable vapor, and organic dust flash fires typically generate temperatures from 1000°F to 1900°F (538°C to 1038°C). Metal dust flash fires can generate higher temperatures [see Table A.22.1.1.3]. 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. High thermal radiation heat flux produced by most metals significantly enlarges the hazard areas beyond the fire ball.

Another type of short duration fire can occur when a stream of combustible metal or vapor flows past a stationary ignition source (sometimes referred to as a jet fire). This short duration flame poses similar hazards to a flash fire in the form of a deflagration and should be considered as part of the dust hazards analysis (DHA). (CMD-CMM)

A.3.3.53 Garments. Outerwear includes, but is not limited to, rainwear, flame-resistant chemical protection suits, leggings, gauntlets, and other protective garment systems. [2113, 2025] (CMD-FUN)

A.3.3.59 Hog (Wood Hog). Examples of wood hogs include but are not limited to hammer mills, board breakers, shredders, or other similar coarse size reduction equipment. (CMD-WOO)

A.3.3.61 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 pose a flash fire or explosion hazard, even if the dust is below the MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitable 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. (CMD-FUN)

A.3.3.62 Identified (as applied to equipment). Some examples of ways to determine suitability of equipment for a specific purpose, environment, or application include investigations by a qualified testing laboratory (listing and labeling), an inspection agency, or other organizations concerned with product evaluation. [70, 2023] (CMD-FUN)

A.3.3.63 Ignitable Liquid. Class I liquids [FP < 100°F (37.8°C)] and Class II and Class III liquids [FP ≥ 100°F (37.8°C)] are all ignitable liquids. (See Annex B of NFPA 30 for more information.) (CMD-FUN)

A.3.3.65 Ingredient Transport System. Clean human and animal food (see 3.3.50) ingredients include only materials that are immediately suited to be put into the edible food product and excludes any contaminants or foreign objects.

An example of an ingredient transport system might include a day bin, convey system, scale hopper, and/or other intermediate vessel(s). Vessels located outdoors such as silos, rail loadouts, and truck loadouts are not included. (CMD-AGR)

A.3.3.66.1 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. (CMD-FUN)

A.3.3.66.2 Rigid Intermediate Bulk Container (RIBC). These are often called *composite IBCs*, which is the term used by the US 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. (CMD-FUN)

A.3.3.68 K_{st} . The deflagration index, K_{st} , is computed from the maximum rate of pressure rise, $(dP/dt)_{max}$, attained by combustion in a closed vessel with volume, V , and is defined by the following equation:

[A.3.3.68]

$$K = \left(\frac{dP}{dt} \right)_{max} \cdot V^{1/3}$$

[68:6.1.1] (CMD-FUN)

A.3.3.69 Limiting Oxidant Concentration (LOC). LOC is dependent on inert gas used and is determined using ASTM E2931, *Standard Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*. Some common inert gases like

carbon dioxide or nitrogen are not effective with some combustible metals. Argon can be used with most metals. (CMD-FUN)

A.3.3.72 Lower Flammable Limit (LFL). LFL is in reference to gaseous fuels and is analogous to minimum explosible concentration (MEC) for combustible dusts. (CMD-FUN)

A.3.3.75 Mesh Size. Table A.3.3.75 provides mesh sizes. (CMD-FUN)

A.3.3.76 Metal. An opaque lustrous elemental chemical substance that is a good conductor of heat and electricity and, when polished, a good reflector of light. Commercially pure metals have no alloying elements deliberately added. Most elemental metals are malleable and ductile and are, in general,

denser than other elemental substances. As to structure, metals can be distinguished from nonmetals by their atomic binding and electron availability. (CMD-CMM)

A.3.3.76.2 Legacy Metals. These specific metals had individual chapters in previous editions of NFPA 484. For consistency and convenience, these requirements have been pulled into a single section. The requirements have not changed. See 22.1.1.3 for additional guidance for alloys. (CMD-CMM)

A.3.3.76.4 Metal-Containing Mixture. Intentional mixtures range from formulations by blending or compounding of metals with non-metals (organics, salts, inorganics) for use as intermediates, final products, or inertants, or for recycling or waste treatment. Examples of mixtures as products include powder coating formulations and blended metals for powder metallurgy or alloy production. Rock dusts (such as limestone, dolomite, and magnesite) have been used as solid inertants to inert or suppress dust explosions. Examples of mixtures for recycling or waste treatment are metal turnings, chips, fines, powder, or dust from the finishing operation of two or more metals or alloys, and metal turnings, chips, fines, powder, or dust containing debris from abrasive media (alumina, silicon carbide, boron carbide, diamond, cubic boron nitride, garnet, and quartz) from grinding, honing, lapping, superfinishing, polishing, pressure blasting, or barrel finishing; mixed with water, cleaning agents and/or cutting oils. Metal alloys, organo-metallics, salts and metal oxides, sulfides, silicates, etc. are not metal mixtures because they are bonded either chemically on in their lattice structures. Mixtures do not include contamination. The original composition could be segregated into the individual components during size reduction or handling. (CMD-CMM)

A.3.3.78 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 analogous 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. (CMD-FUN)

A.3.3.79 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*.

To characterize electrostatic discharge ignition hazards, it is recommended that the ASTM E2019 test be conducted without added inductance, which is equivalent to a capacitive spark discharge.

To characterize ignition hazards from thermal sparks and electrical or electronic equipment, it is recommended that the ASTM E2019 test be conducted with inductance. (CMD-FUN)

A.3.3.80 Mixture. Mixtures can pose unique hazard management challenges depending upon the constituents. For exam-

Table A.3.3.75 Mesh Designations

US Standard Mesh Designation	Mesh Size		
	mm	µm	in.
4	4.750	4750	0.1870
5	4.000	4000	0.1570
6	3.350	3350	0.1320
7	2.800	2800	0.1110
8	2.360	2360	0.0937
10	2.000	2000	0.0787
12	1.700	1700	0.0661
14	1.400	1400	0.0555
16	1.180	1180	0.0469
18	1.000	1000	0.0394
20	0.850	850	0.0331
25	0.710	710	0.0278
30	0.600	600	0.0234
35	0.500	500	0.0197
40	0.425	425	0.0165
45	0.355	355	0.0139
50	0.300	300	0.0117
60	0.250	250	0.0098
70	0.212	212	0.0083
80	0.180	180	0.0070
100	0.150	150	0.0059
120	0.125	125	0.0049
140	0.106	106	0.0041
170	0.090	90	0.0035
200	0.075	75	0.0029
230	0.063	63	0.0025
270	0.053	53	0.0021
325	0.045	45	0.0017

ple, mixtures consisting of reactive metals mixed with plastics or cellulosic materials can lead to unexpected reactions when water or sodium bicarbonate is used to prevent or extinguish fires, flash fires, or explosions. It is important to identify the predominant portion of the mixture in order to determine which industry- or commodity specific standard applies. (CMD-FUN)

A.3.3.81 Moisture Content (Wet Basis). The moisture content is determined by completely drying a sample and dividing the amount of water driven off by the original sample mass. If a 1 kg sample of wood is dried to the point where no additional weight loss can be obtained with additional drying and the sample is then weighed and weighs 0.75 kg, the moisture content is as follows:

$$\frac{[(\text{sample wt before}) - (\text{sample wt after})]}{\text{sample wt before}} = \frac{1 \text{ kg} - 0.75 \text{ kg}}{1 \text{ kg}} = 25\% \quad [\text{A.3.3.81}]$$

The conversion from wet basis to dry basis is illustrated in Figure A.3.3.81. (CMD-WOO)

A.3.3.82 Nanometal Powder. Although nanomaterials are usually defined as particles smaller than 100 nanometers (0.1 μm), larger particulates with diameters of almost 500 nanometers (0.5 μm) also exhibit special ignitability characteristics and enhanced combustibility and explosibility. For example, LOC data reported by Mittal 2014 shows the LOC for magnesium is 5 percent for a particle size range of 38 μm to 125 μm and decreases to 3 percent for a particle size of 400 nanometers (0.4 μm). (CMD-CMM)

A.3.3.84 Noncombustible Material. When used in the context of materials of construction, materials that are reported as having passed ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, should be considered noncombustible materials. For the purposes of this standard, noncombustible construction and

limited-combustible construction are both considered to be noncombustible. In this document, the term *noncombustible material* is also used to refer to process materials that do not present a fire, flash fire, or explosion hazard as per Chapter 5. (CMD-FUN)

A.3.3.85 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. (CMD-FUN)

A.3.3.93 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, and so forth, 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.

For high-risk materials (e.g., some metal powders with low MIE), the use of a “closed-loop” pneumatic conveying system (i.e., dilute, dense, or semi-dense phase) with a suitable inert gas as the conveying medium is a feasible approach for transferring such materials from one location to another. Special design considerations could be necessary. (CMD-FUN)

A.3.3.94 Powder (Metal). Typically, powders are less than 0.04 in. (1 mm) and can be elemental or alloy in composition and regular, irregular, spherical, sponge, granular, dendritic, or nodular in shape. (CMD-CMM)

A.3.3.94.1 Aluminum Flake Powder. Certain “nondusting” grades of aluminum flake powder are being produced. Although they exhibit less tendency to be dispersed into a dust cloud, the precautions described in this standard should nevertheless be observed. (CMD-CMM)

A.3.3.94.3 Aluminum Powder. The length, width, and thickness of an atomized particle or granule are all of approximately the same order, the length dimension probably not exceeding

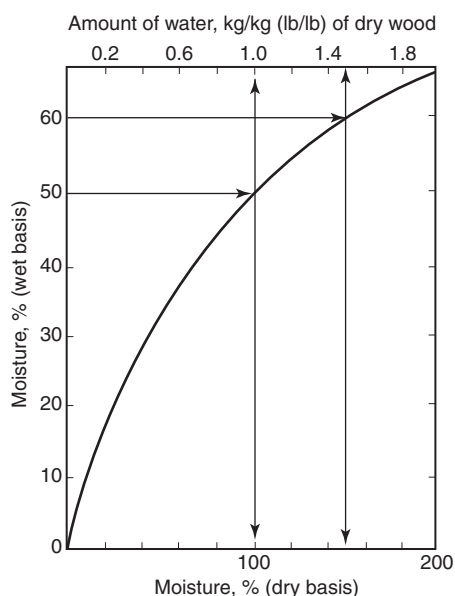


FIGURE A.3.3.81 Conversion from Wet Basis to Dry Basis.

two or three times the thickness dimension. The length or width of a flake is several hundred times its thickness. Granules are generally powders larger than 75 μm (200 mesh). (CMD-CMM)

A.3.3.94.4 Combustible Metal Powder. See NFPA 499 or NFPA 497 for information on explosibility parameters of combustible dusts. (CMD-CMM)

A.3.3.95 Powder Production Plant. Facilities or buildings in which powder or combustible dust is produced incidentally to operations are not considered powder production plants. (CMD-CMM)

A.3.3.96 Propellant-Actuated Device. As defined in OSHA 1910.109(a)(8), propellant-actuated devices are those using smokeless propellants. For this document, the term is also applied to tools or devices that use combustion of a fuel-air mixture within a confined chamber to do work. An example of this type of tool would be a nail driving tool using compressed or liquefied gas as the fuel source. (CMD-FUN)

A.3.3.97 Pyrophoric Material. Dispersions of alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, the solvent presents the concerns of ignitable (flammable and combustible) liquids and vapors. In addition to the SDS provided by the supplier of the material, NFPA 30 and NFPA 77 are applicable to addressing the problems of ignitable liquids and vapors. (CMD-CMM)

A.3.3.100 Recycling. Recycling includes, but is not limited to, mechanical and chemical processing, crushing, grinding, shearing, baling, compacting, and so forth. Where a new chemical compound is made, or materials are consolidated or processed such that its form is no longer recognizable from the original raw material, it is considered manufacturing, not recycling. (CMD-FUN)

A.3.3.102.1 Magnesium Ribbon. It should be considered a powder for storage. (CMD-CMM)

A.3.3.103 Risk Assessment. A risk assessment is a process that performs the following:

- (1) Identifies hazards that could lead to an event with undesired consequences
- (2) Estimates the consequences and likelihood (probability) of the event
- (3) Determines the risk of the event (function of consequences and likelihood)
- (4) Evaluates the risk against established risk tolerance criteria
- (5) Identifies potential risk reduction options
- (6) Selects the appropriate risk reduction options that would reduce the risk to a tolerable level

A risk assessment requires that the company has established risk tolerance criteria (maximum tolerable levels of risk) to guide its decision-making.

Risk assessments can be qualitative, semiquantitative, or quantitative. Qualitative methods are usually used to identify the most hazardous events for further evaluation. Semiquantitative methods are used to determine relative hazards associated with unwanted events and are typified by indexing methods or numerical grading — for example, via the use of a risk matrix. Quantitative methods are the most detailed and use a probabilistic approach to quantify the risk.

Likelihood in context of a risk assessment is an estimation of the expected frequency of the occurrence of the event typically expressed in frequency (number of events in a given time-period) or a probability (10 percent chance each year). There are many sources of data depending on the initiating cause that can assist in estimating the frequency.

Consequence of a dust fire or explosion can range from no injuries and minimal asset damage to multiple fatalities and the total loss of the asset. Consequences can be estimated qualitatively using industry experience or more quantitative with the use of computational models.

Great care must be given when estimating the likelihood or consequence based solely on incident data for a site because an event that would occur once in 10 or 20 years is beyond the experience of the individual or team completing the risk assessment. It is possible that the assessors could underestimate the frequency or consequence of an event that they have never experienced.

Risk tolerance is the maximum level of risk an owner is prepared to accept when making decisions in the implementation of controls to manage the hazards associated with combustible dust. There exists industry guidance for establishing risk tolerance criteria.

See *SFPE Engineering Guide to Fire Risk Assessment*, *CCPS Guidelines for Hazard Evaluation Procedures*, *CCPS Guidelines for Combustible Dust Hazard Analysis*, or *CCPS Guidelines for Developing Quantitative Safety Risk Criteria*, for more information.

A common goal of risk control is to reduce the risk to “as low as reasonably practicable” (ALARP). This concept states that risk reductions should continue until the incremental cost of further risk reduction greatly exceeds the benefit of doing so. Figure A.3.3.103(a) is commonly known as the ALARP carrot diagram from the UK HSE (Health and Safety at Work etc. Act 1974). It shows that there are risks, at the top of the diagram, that are so great that they must be reduced or operations must be stopped. The bottom of the diagram shows that there are risks so low that can be tolerated without further risk reduction efforts. In the middle of the diagram, the risks require further reduction until ALARP is achieved. Note that the risk tolerance criteria in the diagram are for the total risk that a worker might be exposed to, rather than the risk of a single scenario. (CMD-FUN)

A risk matrix, as shown in Figure A.3.3.103(b), is a commonly used tool developed by owners to assist in the determination of the level of risk for a specific hazard scenario.

A.3.3.107.1 Attrition-Style Size Reduction Equipment. The size reduction in attrition machines is accomplished by collision between and abrasion of particles. Power for moving the particles is furnished by compressed air or other fluid suitable to the material being pulverized. (CMD-HAP)

A.3.3.108 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. (CMD-FUN)

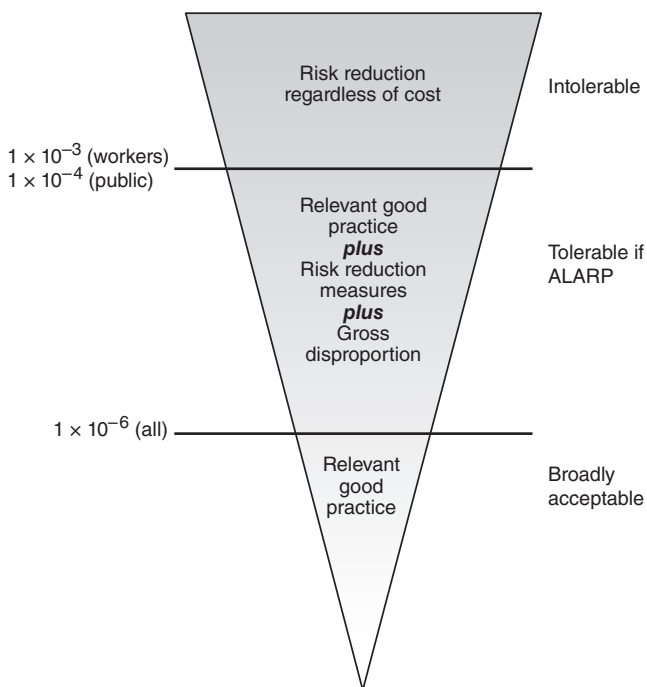


FIGURE A.3.3.103(a) ALARP Carrot Diagram from the UK HSE (Health and Safety at Work etc. Act 1974).

A.3.3.108.1 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. (CMD-FUN)

A.3.3.108.2 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. (CMD-FUN)

A.3.3.109 Spark-Resistant Material. See AMCA Standard 99, *Standards Handbook*, for additional information. (CMD-FUN)

A.3.3.110 Sponge. Sponge can contain dust and fines that can become airborne when the material is handled. If present in sufficient quantity, the dust and fines can cause increased fire risk. (CMD-CMM)

A.3.3.114 Sulfur Dust. The committee is aware of data contained in Eckhoff, *Dust Explosions in the Process Industries*, Table A1, which reported positive explosion test results of a sulfur dust cloud with a median particle size of 120 μm as being explosible. (CMD-HAP)

A.3.3.120 Thermite Reaction. There is a potential for a thermite reaction between metal alloys and iron oxide at elevated temperatures.

Iron scale and molten metal can create a thermite reaction. The interior of a crucible furnace, normally known as the “setting,” is a critical area of concern. With the use of sulfur hexafluoride (SF₆) and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern. (CMD-CMM)

A.3.3.125 Ultrafine Particle. It is important for the user of this standard to be aware that ultrafine particles can present additional hazards that should be considered. Examples of additional hazards are the possible lowering of the MIE or MEC levels, or both, the potential for particulates passing through filtration devices used in dust collection, pneumatic conveying, and so forth. The committee recognizes that the definition for ultrafine particles is wider than the definition in ASTM E2456, *Standard Terminology Relating to Nanotechnology*, but has adopted this increased range because of the additional potential hazards associated with ultrafine particles. When the median size is <0.5 μm (<500 nm), it is more likely that part of the size distribution will be lower than 0.1 μm (100 nm), and therefore a more detailed characterization and hazard assessment specific to ultrafine particles will be necessary.

Nanopowders and nanoparticles, which fall under this definition, are becoming more prevalent as specific-use materials in such industries as additive manufacturing. (CMD-FUN)

A.3.3.129 Water-Compatible. These materials include many of the cellulose materials such as wood waste, paper dust, textile fibers, bulk agricultural products, municipal solid waste (MSW), refuse-derived fuel (RDF), and other organic materials, including coal and some plastic resins. Water spray extinguishment can be used for these materials when they are handled in systems in which the process equipment is also water-compatible. (CMD-FUN)

A.3.3.130 Water-Incompatible. Water-incompatible materials are typified by those that dissolve in water or form mixtures with water that are no longer processable — for example, sugar. Although water is an effective extinguishing agent for sugar fires, the sugar dissolves in the water, resulting in a syrup that can no longer be processed pneumatically. A similar situation exists with flour; when mixed with water, it becomes dough. These materials are candidates for extinguishing systems that use media other than water until the damage potential of the fire approaches the replacement cost of the process equipment. Then water is used to protect the structure. (CMD-FUN)

A.3.3.131 Water-Reactive. Water-reactive materials represent a very special fire protection problem. The application of water from fixed water-based extinguishing systems or by the fire service without awareness of the presence of these materials could seriously exacerbate the threat to human life or property. For example, many chemicals form strong acids or bases when mixed with water, thus introducing a chemical burn hazard. Additionally, most metals in the powdered state can burn with sufficient heat to chemically reduce water-yielding hydrogen, which can then support a deflagration.

These types of materials should be handled very carefully. Small quantities of water usually make matters worse. (CMD-FUN)

A.3.3.133.1 Deflagrable Wood Dust. Dusts traditionally have been defined as a material 420 μm or smaller. More recent data on wood particulates suggests that particulates with a major dimension as large as 0.2 in. (5 mm) could pose a deflagration hazard. Particulate surface area-to-volume ratio is a key factor in determining the rate of combustion. For consistency with more recent test data and other standards, 500 μm is now considered an appropriate size criterion. The particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum

Consequence Range	Safety Consequence Criteria	
Level 4	Personnel – one or more fatalities Public – disabling injury or fatality Environmental – uncontained release with major environmental impact Equipment – plant damage/loss value in excess of \$1 million	
Level 3	Personnel – for disabling injury Public – injury requiring physician's care Environmental – uncontained release with medium environmental impact Equipment – plant damage/loss value in excess of \$100,000 to \$1 million	
Level 2	Personnel – a lost workday injury Public – an injury requiring first aid Environmental – uncontained release with minor environmental impact Equipment – plant damage/loss value in excess of \$100,000	
Level 1	Personnel – a recordable injury Public – odor or noise nuisance, no direct impact Environmental – contained release with localized impact Equipment – no significant loss	
Likelihood Range	Event Frequency	Description
Level 5	> 1/yr	Is likely to occur once a year or more
Level 4	1/yr to 10-1/yr	Is likely to occur between once a year up to once in 10 years
Level 3	10-1 to 10-2/yr	Is likely to occur between once in 10 up to once in 100 years
Level 2	10-2 to 10-3/yr	Is likely to occur between once in 100 up to once in 1000 years
Level 1	< 10-4/yr	Is likely to occur between once in 1000 up to once in 10,000 years

Risk Level	Team Action
A	Risk mitigation required to risk level D
B	Risk mitigation required to risk level D
C	Risk mitigation required to risk level D
D	No further risk mitigation required

Likelihood	5	C	B	A	A
	4	D	C	B	A
	3	D	D	C	B
	2	D	D	D	C
	1	D	D	D	D
		1	2	3	4
		Consequence			

FIGURE A.3.3.103(b) Risk Matrix.

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 particle that has a major dimension as large as 0.2 in. (5 mm) could behave as a deflagrable wood dust if suspended in air.

It is critical to keep in mind that as particulate is processed, handled, or transported, the particle size generally decreases due to particle attrition.

The determination of whether a sample of material is a combustible (explosible) dust should be based on a screening test methodology such as provided in the draft ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, can be used to determine dust explosibility.

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 ASTM E1515 test. This is due to the high-energy ignition source over-driving 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 over-driving and thus will provide more realistic results.

This possibility for false positives has been known for quite some time and is attributed to over-driven conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m³ chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from a 1 m³ chamber for most dusts. In fact, the US 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 m³ 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 m³ chamber."

NFPA 68 also recognizes this problem and addresses it, stating: "The 20 L test apparatus is designed to simulate results of the 1 m³ chamber; however, the igniter discharge makes it problematic to determine K_{St} values less than 50 bar-m/sec. Where the material is expected to yield K_{St} values less than 50 bar-m/sec, testing in a 1 m³ chamber might yield lower values."

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) Minimum explosible concentration (MEC)
- (2) Minimum ignition energy (MIE)
- (3) Particle size distribution
- (4) Moisture content as received and as tested
- (5) Maximum explosion pressure at optimum concentration
- (6) Maximum rate of pressure rise at optimum concentration
- (7) K_{St} (normalized rate of pressure rise) as defined in ASTM E1226
- (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

Consequently, it is often necessary to evaluate the explosibility of the particulate at multiple points along the process. Where process conditions dictate the use of oxidizing media other than air (nominally taken as 21 percent oxygen and 79 percent nitrogen), certain of the above tests should be conducted in the appropriate process specific medium. (CMD-WOO)

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) Flash fire (combustion in suspended dust cloud)
- (5) Explosion rupturing equipment
- (6) Explosion rupturing rooms or buildings

A.4.2.1.1 Given the fast-acting nature of flash fires 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 ft³ (0.2 m³) air-material separator not requiring protection; however, the intent of the objective is to consider the effect of flash fires and explosions 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, flash fire, or explosion origin. The intent is to prevent the collapse of the structure during the fire, flash fire, or explosion.

A.4.2.4(2) 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, flash 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. Refer to Chapters 21, 22, 23, 24, and 25 for the prescriptive hazard management requirements in the relevant industry- or commodity-specific chapters.

A.5.1 For hazard identification, the following material properties should be addressed by a DHA per Chapter 7 for the combustible particulate solids present when determining combustibility or explosibility:

- (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 flash fire or explosion.
For a sub-500 micron fraction, the following applies:
 - (a) Data is 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 the explosibility 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 μm are generally not considered to pose a flash fire or explosion potential. 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. 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 flash fire or explosion hazard in the ullage space.
- (3) *Particle Shape.* Due to particle shape and agglomeration, some particulates cannot be sieved effectively. Particulates with nonspherical or noncubic shapes do not pass through a sieve as easily as spheric or cubic particles. For this purpose, long fibers can pose a deflagration hazard comparable to 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.
- (4) *Particle Aging.* Some combustible particulate solid materials could undergo changes in their explosibility 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. Agglomerated particulates can act like larger particles if the agglomerates are not broken up before or during testing. For hydrophilic materials, agglomeration is usually affected by ambient humidity, which increases the moisture content of the particles. For this reason, test protocols typically specify a maximum sample moisture content prior to testing.
- (8) *Electrostatic Attraction.* Particles with a chemistry that allows electrostatic charge accumulation will become charged during handling. Charged particles attract oppositely charged particles leading to agglomeration that can result in nonconservative explosibility metrics during testing. Humidification can decrease the electrostatic attraction but refer to A.5.1(7).
- (9) *Entrainment Fraction.* The calculation for a dust dispersion from an accumulated layer should consider the ease of entrainment of the dust. Dispersion is generally a function of humidity, temperature, and time. Hydrophilic materials can form cohesive layers that might not be dispersible. Particle shape and effective particle size should be considered.
- (10) *Combustible Concentration.* A dust dispersion can come from a layer of accumulated fugitive dust. 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). 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 in Equation A.5.1.

[A.5.1]

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

- (11) *Competent Ignition Source.* Ignition occurs where sufficient energy per unit of time and volume is applied to a suspended combustible dust cloud. When the temperature of the suspension is increased to the autoignition temperature (AIT), combustion begins. Ignitability is usually characterized by measuring the minimum ignition energy (MIE).

- (12) *Conditions Required for Flash Fires and Explosions.* Refer to A.7.2.1 for a description of the conditions required for a combustible dust flash fire or explosion to occur.

A.5.2.1 Data derived from testing material sampled from the process being reviewed will be the most representative of the process. The intent of a representative sample is to match the particulate under consideration with respect to chemical composition, particle size, particle size distribution, particle morphology, moisture content, and sampling location.

A.5.2.2 Testing is not required to determine whether the material has combustibility characteristics where reliable, in-house, industry- or 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 purposes if a thorough review indicates that the data are representative of owner/operator conditions.

Annex Y contains examples of test data for selected combustible dusts with known explosion data parameters. Other databases, such as the IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance) GESTIS-DUST-EX Database Combustion, are available for data on explosion characteristics of dusts.

A.5.2.3 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 or not the material is known to be combustible. 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 5.2.3 does not require the user to know all these items for the assessment; rather, it reviews the important items in order to determine whether the material data are representative of the material in the facility. Even test data of material can be different from the actual conditions. Users should review the conditions of the test method as well to ensure that it is representative of the conditions of the facility. Where that is not possible, the use of worst-case values should be selected.

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

Refer to Annex Y for examples of combustible dust test data.

A.5.2.4 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 fires, flash fires, explosions, or evidence of vessel, tank, or container overpressure should not be used as a substitute for hazards analysis. Process incidents can be used to guide or select samples for and supplement testing.

A.5.3 Some materials have multiple potential physical hazards such as combustibility, explosibility, reactivity, and propensity to self-heat. Reactivity hazards can release energy and produce products that are more readily ignitable than the original material, thus creating or exacerbating a combustion hazard that would be within the scope of a DHA. Reactivity of combustible particulates by means other than self-heating could occur due to thermal instability or contact with an incompatible material. The ensuing chemical reaction could generate heat and gases, and the gases generated could be toxic, corrosive, or flammable.

Identification of potential incompatibility with water should be a high priority because humidity in the air might be sufficient to initiate reactions with materials that are incompatible with water. The need to know whether to avoid material contact with water is important, since water is often present at the site for process use, cleaning, utility use, or emergency response. Water is often the first choice as a fire extinguishing agent, so knowing whether to use or avoid water when extinguishing fires is critical.

Users should consult safety data sheets (SDS) for specific information and guidance on safe handling, personal protective equipment (PPE), and storage and transportation of chemicals.

A.5.3.1.2.2 A typical protocol involves using at least two different size baskets of representative particulate in an oven at several specified temperatures and with temperature sensors in the basket, to determine if and when the particulate temperature exceeds the oven temperature. One commonly used version of the oven basket tests for self-heating is UN Test N.4, "Test Method for Self-heating Substances" in *Recommendations for the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria*, which is used to determine if a material should be designated as Division 4.2, "Substances Liable to Spontaneous Combustion." BS EN 15188, *Determination of the spontaneous ignition behavior of dust accumulations*, is another widely used version of oven basket tests.

A.5.3.1.2.3 As a simple example, the UN Test N.4 data analysis method designates a material as a self-heating substance if a 100 mm (3.9 in.) sample undergoes self-heating in an oven at 140°C (284°F). More general data analysis methods are described, for example, in J. C. Jones's article, "Recent Developments and Improvements in Test Methods for Propensity Towards Spontaneous Heating," in *Fire and Materials*.

A.5.3.2.2.2 When conducting testing for temperature sensitivity, the use of nitrogen in place of air can help distinguish between an oxidation reaction and a thermal decomposition. Differential scanning calorimetry, thermal gravimetric analysis, and similar thermal analysis test methods are often used to test for thermal decomposition and polymerization reactions. For more information, see Chapter 3 in the CCPS *Guidelines for Safe Handling of Powders and Bulk Solids*.

A.5.3.3.2.1 The US DOT Pipeline and Hazardous Materials Safety Administration *Emergency Response Guidebook (ERG)* contains the "Table of Water-Reactive Materials Which Produce Toxic Gases." Potential reactivity screening tools include the CCPS Chemical Reactivity Worksheet (CRW) and the AIChE Chemical Hazard Engineering Fundamentals (CHEF) documentation.

A.5.3.4.2.2 Differential scanning calorimetry is often used as a preliminary screening test for reactive materials. Other calorimetric reactivity test methods include ARC, APTAC, and VSP2. For more information, see Chapter 4 in the CCPS *Guidelines for Safe Handling of Powders and Bulk Solids*.

Where the material decomposition products are likely to be hazardous, the identification and quantification of the byproducts should be obtained.

A.5.4.1.1(1) Note that a material that does not propagate combustion in the UN Test N.1, “Test Methods for Readily Combustible Solids,” can still be explosible.

A.5.4.1.1(2) An example of an equivalent test method would be VDI 2263 Part 1, *Test Methods for the Determinations of Safety Characteristics Dusts*, section 1.1 or section 1.2. For this test method, materials that are Class 1, 2, or 3 are considered noncombustible [equivalent to A.5.4.1.2(1), A.5.4.1.2(2), and A.5.4.1.2(3)], and materials that are Class 4, 5, or 6 are to be considered combustible [equivalent to A.5.4.1.2(4)].

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 standard. 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. The dust hazards analysis should determine the extent to which the requirements of this standard are applicable to this material.

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 standard should 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, hazards analysis should focus on additional protocols and compliance with other NFPA standards.

A.5.4.2 Many combustible dusts can potentially burn while suspended in air without any confinement, producing a flash fire hazard to nearby personnel. Some materials might produce a flash fire hazard but not produce enough pressure to pose an explosion hazard. 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.

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 Z.1.2.24, articles by Bouillard and Wu.)

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 0.5 in.

(12.7 mm) 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.

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 $265 \pm 25^\circ\text{C}$ 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.

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 deflagration 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 499, NFPA 68, and this standard have lists of combustible and explosive 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.

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 hazardous sample. See 5.5.2.

Table A.5.4.4.1 Standard Test Methods to Determine Explosibility Properties

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

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.

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 Explosibility 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.

A.5.5.4.1 Identifiers could include lot, origin, composition (pure, mixture), process, age, location, and date collected. 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.6.1.3.1 The *SFPE Engineering Guide to Performance-Based Fire Protection* describes one form of documentation that could 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.

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*, which are widely recognized technical sources of information

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

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

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

A method to address a specific fire, flash 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 combustibility or explosibility testing.

A.6.1.4.10.1 The term *model* in 6.1.4.10.1 is meant to address computer methods like, but not limited to, computational fluid dynamics (CFD) or finite element analysis (FEA), or simple computations performed by hand.

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 8.11.

A.6.1.6.1 Chapter 70, “Dust Explosions,” of the *SFPE Handbook of Fire Protection Engineering* provides data sources that can be used in a performance-based design.

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 requirement 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 When evaluating tenable conditions, the toxicity of hazardous materials released as a result of a fire, flash fire, or explosion should be considered. Untenable conditions in explosion scenarios include missile impact or overpressure.

A.6.3.2 SFPE S.01, *Engineering Standard on Calculating Fire Exposures to Structures*, provides methodologies to predict thermal boundary conditions for fully developed fires to structures. SFPE S.02, *Engineering Standard on Calculation Methods to Predict the Thermal Performance of Structural and Fire Resistive Assemblies*, provides requirements for the use of methods that predict the thermal response of structures.

A.6.3.5(3) The designed operation of the deflagration vent does not constitute a rupture or failure of the building or equipment. A properly designed deflagration vent should not create fragments that can constitute missile hazards.

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, flash 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 An example of the flash fire or explosion hazards is generation of hydrogen or other flammable gases. Some combustible metals can generate hydrogen when in contact with water. See Chapter 22 for additional information.

A.6.5 The *SFPE Guidelines for Peer Review in the Fire Protection Design Process* address the process of conducting an independent third party review for a fire protection design.

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.

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.

The term *DHA* should not be construed to mean that the hazards to be assessed are limited to those posed by combustible dusts. The intent of the DHA is to evaluate fire, flash fire, and explosion hazards, which includes the consideration of combustible particulate solids with particle sizes greater than that associated with dusts.

See the CCPS *Guidelines for Combustible Dust Hazard Analysis* for additional guidance on analyzing combustible dust hazards.

A.7.1.1.2 A DHA is a careful review of the fire, flash 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. A DHA should be completed as soon as possible. For existing facilities, those processes with the greatest perceived risk should be evaluated first.

A.7.2.1 This standard relies on the determination of where a fire, flash fire, or explosion hazard exists. The DHA should consider the conditions that are required for these events.

For a fire in settled solids to occur, there needs to be all of the following:

- (1) A combustible particulate solid in sufficient quantity for a flame to propagate
- (2) Air or other oxidizing atmosphere
- (3) A competent ignition source applied to the combustible particulate solid

See Figure A.7.2.1(a).

For a flash fire to occur, there needs to be all of the following:

- (1) A combustible particulate solid of sufficiently small particle size
- (2) Air or other oxidizing atmosphere
- (3) A means for suspending the combustible particulate solid at a sufficiently high concentration
- (4) A competent ignition source applied to the suspension of combustible particulate solids where the concentration is sufficient for flame propagation

See Figure A.7.2.1(b). For an explosion to occur, a fifth factor must be present — that is, the flash fire must be sufficiently confined to allow the accumulation of a damaging level of pressure. See Figure A.7.2.1(c).

Often, dust explosions occur in a series. Primary explosions lead to secondary explosions, usually fueled by accumulated fugitive dust that has been suspended either by being dislodged by the shaking of the building or equipment or by entrainment by the pressure front caused by the previous explosion.

The majority of the property damage and personnel injury can be due to these secondary explosions that result from the fugitive dust accumulations within the building or process compartment. The elimination of accumulated fugitive dust is critical and is often the single most important criterion for a safe workplace.

While the primary focus of the DHA is the hazards associated with combustible dusts and particulate solids, there are other physical and health hazards to consider when conducting the DHA such as toxicity and reactivity of the particulate solids with water. There can also be fire, flash fire, or explosion hazards associated with ignitable (flammable or combustible) liquids as part of the process covered by this standard. Note that NFPA 30 provides additional requirements for ignitable (flammable or combustible) liquids hazards.

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 as little as two persons, or for larger and more complex processes, the team might require many more

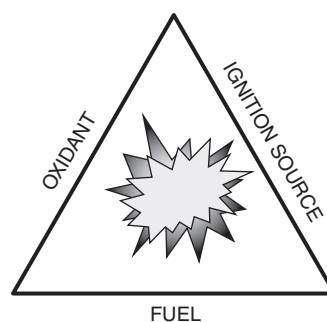


FIGURE A.7.2.1(a) Fire Requirements.

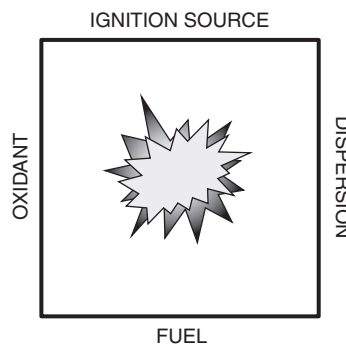


FIGURE A.7.2.1(b) Flash Fire Requirements.

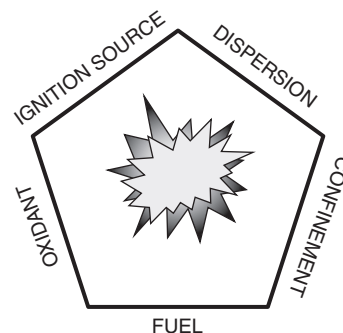


FIGURE A.7.2.1(c) Explosion Requirements.

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.

Someone who is qualified to perform or lead a DHA has performed all the aspects of several DHAs associated with the affected industry or type of combustible dust(s). This individual has a working understanding of the intent of the numerous combustible dust standards and can recognize safe and cost-effective solutions that fit each facility's needs. This specialized knowledge and experience that comprise an individual's qualifications are gained from months to years of work assessing and mitigating complex combustible dust fire and explosion scenarios. However, this expertise cannot be gained by merely observing a DHA, reading standards, or attending a training course. Simply being a certified environmental, safety, and health (EHS) professional (e.g., CIH, CSP) or licensed professional engineer (PE) in and of itself also does not mean an individual possess the necessary skills and required knowledge to perform a DHA. The complexities associated with analyzing the combustible dust hazards in processes, equipment, and building compartments demand specialized expertise beyond just certifications and licenses. Because the characteristics of being qualified and unqualified are dependent on the type of combustible dust, an individual might also only be qualified to perform a DHA for a specific type of combustible dust. Failure to acknowledge one's qualifications or lack thereof could cause fire and explosion hazards to be misidentified, incorrectly mitigated, or worse, both.

A.7.2.3 The report prepared to document the results of the DHA should include relevant supporting information including, but not be limited to, the following:

- (1) Test reports
- (2) Drawings and specifications
- (3) Design calculations

A.7.3.1(2)(b) Consequences of combustible dust hazards can be prevented or mitigated by using the methods in this standard.

A.7.3.3.1 This evaluation includes the process systems and ancillary equipment such as dust collection systems. Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate.

A.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 deter-

mine which option is most appropriate. (*Refer to Annex B for an example of a process hazard analysis.*)

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.*)

The DHA for building compartments should distinguish between localized flash fire hazards and conditions that present a hazard of a propagating deflagration through a suspended dust accumulation throughout a building compartment or portion thereof. The DHA should document where each hazard exists in the building compartment as this information is needed in order to comply with 8.6.1.

A.7.3.4.2.1 Refer to 25.7.3.1.3 and 24.7.3.4.1 for examples of methods to determine acceptable threshold accumulation level. Other industry- or commodity-specific chapters provide alternate guidance.

A.8.1 The DHA will determine where fire, flash fire, or explosion hazards exist in process equipment or in building compartments. However, such hazards might not exist uniformly throughout a facility. Certain requirements in this chapter would not be mandatory for equipment or building compartments where the DHA has determined that a fire, flash fire, or explosion hazard does not exist. However, consideration should be given to generally applying a particular requirement when a fire, flash fire, or explosion hazard exists in at least a portion of the facility. For example, operating procedures would be required for equipment where a fire, flash fire, or explosion hazards exist. Rather than seeking to discriminate between those items of equipment that do, or do not, require operating procedures, the owner/operator might find it more effective to provide operating procedures for all process equipment.

A.8.2 See ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems*.

A.8.3 See CCPS *Guidance for Writing Effective Operating and Maintenance Procedures* for guidelines for procedures.

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 Where a dust explosion hazard or dust flash-fire hazard exists, flame-resistant garments provide a measure of protection for exposed personnel.

A.8.3.3.1 The policy should include the type, use, and location of appliances. The intent of this procedure is to recognize the inherent hazards associated with the use of appliances in certain locations. Any exception to this written policy should be reviewed on a case-by-case basis. All exceptions should require written approval from the facility manager.

A.8.3.3.2 Electrical appliances should be permitted only in locations where they are suitable for the electrical classification of the space and there are authorized, designated locations intended to support these types of appliances.

Low-hazard locations such as offices, administrative facilities, and distribution centers often allow the following appliances:

- (1) Refrigerators, microwaves, ice machines, small ovens, and coffee makers, located in vending/break room areas or other areas designated by the facility manager
- (2) Fans, radios, and so forth, located in employee's personal work areas as authorized by the facility manager

Care should be taken to ensure that the appliance is not left plugged in and unattended. A person should be appointed to ensure that the appliance(s) is turned off at the end of each working day except for refrigerators, ice makers, and so forth.

Some examples of locations where portable appliances should not be allowed, unless individually evaluated, include the following:

- (1) Manufacturing, storage, fabricating, finishing, or other hazardous areas
- (2) Motor control rooms, computer rooms, computer rack rooms, electrical rooms, or other equipment rooms
- (3) Unoccupied buildings or intermittently occupied areas
- (4) Employee's personal work area, except for small authorized appliances such as fans, radios, and so forth

A.8.3.4 Safe work practices include, but are not limited to, hot work, confined space entry, lockout/tagout, fire and explosion protection systems impairment, 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.8.3.5 A task walk-through is a process where personnel executing a task demonstrate how it is done while being observed by someone else.

Task walk-throughs or field observations of operating or emergency response procedures is an approach to observe and verify the following:

- (1) Procedures are realistic and accurate.

- (2) Safe work practices (e.g., permits) are evident and in good order.
- (3) Operational safeguards are in place.
- (4) Work execution is according to the procedure.
- (5) Personnel executing the task have the necessary competency to perform the work safely.

A.8.4.2.1.1 The housekeeping program should 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 hazards analysis required by NFPA 2113
- (4) Cleaning sequence
- (5) Cleaning methods to be used
- (6) Equipment, including lifts, vacuum systems, and attachments
- (7) Cleaning frequency

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 Explosion and Fire*. 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.

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.

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 Chapters 8 or 9. However, Chapter 22 has specific sections for use of wet and dry portable vacuum cleaning equipment that address their use on alloys and metals such as titanium and aluminum.

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.

A.8.4.2.2.1.7 Verification of the path to ground can be visual.

A.8.4.2.2.1.8 The intention of this requirement is to provide specifications for vacuum cleaners that could be used to remove incidental amounts of combustible dusts from unclassified areas in order to maintain the unclassified area designation.

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 combustible dust hazardous (classified) 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.8.4.2.2.1.8(7) 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.8.4.2.2.1.9(5) This includes consideration of electrical ignition sources (such as electrical devices and electrical motors) as well as mechanical ignition sources (such as rotating parts).

A.8.4.2.2.1.10 The committee is not aware of vendors providing equipment listed for Class III hazardous (classified) 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.

A.8.4.2.4.2 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.

For the specific case of water reactive metals, refer to Chapter 22 for restrictions on the use of water washdown.

A.8.4.2.6.1 Compressed air blowdown used for cleaning purposes has been demonstrated to present significant hazards

associated with the production of combustible dust clouds and should only 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.8.4.2.6.2(3) The discharge pressure 30 psi (207 kPa) is in accordance with OSHA requirements in 29 CFR 1910.242(b), "Hand and Portable Powered Tools and Equipment, General."

A.8.4.2.6.2(4) While elevated lighting might not be within the typical hazardous (classified) location boundaries, the use of blowdown for housekeeping means that a dust cloud could be present at these elevated locations. Installation of lighting for hazardous (classified) locations will permit the use of blowdown methods for cleaning while the lighting is operating. Failure to install suitable lighting would necessitate locking out and tagging out the lighting power supply before commencing blowdown, and lighting for hazardous (classified) locations might have to be provided on a temporary basis while blowdown is being conducted.

A.8.4.5.1 See NFPA 77.

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 Explosion 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 explosion protection features, such as damage limiting/deflagration venting construction or classified electrical equipment, and additional personal protection from dust flash fire or explosion 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)

Ideally, upward-facing surfaces within the facility are painted a contrasting color to the dust that is being handled. This facilitates recognizing when and where accumulations occur. This information then serves to prioritize and schedule cleaning. It is clearly not recommended that the interior surfaces be the same color as the dust that is apt to escape the process and accumulate within the facility.

One method that has proved useful is to print self-adhesive paper or plastic labels with the words "Clean Enough" in bold black type along with a serial number. These labels are installed

at representative locations throughout the facility with the locations recorded on a floor-plan drawing. This allows facility staff to survey the labels at scheduled frequencies and record which labels were “clean enough” to be read, and which were not. This facilitates focusing the housekeeping efforts where the dust accumulations are developing most rapidly.

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 limit. The “accumulation level” of combustible dust defined in Table A.8.4.6.3 should be established in the housekeeping program based on the risk of flash fires and secondary explosions from the dust hazards analysis. If the unscheduled housekeeping fulfills the requirements of the scheduled housekeeping, normal housekeeping must resume before the threshold levels are exceeded.

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.

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 35 ft (11 m).

A.8.5.8 While propellant-actuated tools are not explicitly included in the scope of NFPA 51B, the ignition risk from these tools warrant similar considerations as those applied to powder-driven fasteners that are included as hot work processes. The term *cartridge-actuated tools* can refer to either propellant-actuated or explosive-actuated devices, as well as devices that use noncombustion mechanisms (i.e., compressed air or carbon dioxide cartridges). Devices that use noncombustion mechanisms do not present the same hazards.

A.8.6.1 NFPA 2112-rated FRG can provide a degree of protection but should not be relied upon as a primary means of limiting personnel burn injury.

Historically, operators of facilities have resorted to the use of FRG where the housekeeping program was not sufficient to maintain the level of accumulated fugitive dust below the

threshold housekeeping dust accumulation (maximum layer thickness or threshold mass) computed for the facility in accordance with applicable commodity-specific chapter. However, a review of the performance criteria established in NFPA 2112 for FRG shows that the design criteria are derived from calculations for a defined fire size and exposure time duration. When the size of the deflagration flame or the exposure time exceeds the *thermal dose* for which FRG has been designed, the exposed personnel will probably sustain more severe burn injuries. Consequently, it is critical to distinguish those locations where FRG can be expected to limit burn injury of personnel from those where it cannot.

NFPA 2112 uses a Manikin test where it requires FRG to result in a body burn prediction — that is, total predicted second or third degree burns — of 50 percent or less of the surface area covered by sensors (hands and feet are excluded) when exposed to an overall flame and heat exposure averaging 84 kW/m² for 3 seconds. This criterion corresponds to a significant burn injury that can lead to death. Radiant intensity integrated over exposure time is the *thermal dose*. The resultant thermal dose from a radiant exposure of 84 kW/m² for 3 seconds is 252 kJ/m². This thermal dose establishes the magnitude of the combustion event for which FRG designed in accordance with NFPA 2112 is tested.

A.8.6.1.2 Where the maximum foreseeable thermal dose exceeds 252 kJ/m², FRG designed in accordance with NFPA 2112 might not limit second and third degree burns to 50 percent or less of the body (excluding hands and feet).

A.8.6.2.1 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.8.6.2.3 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.8.6.2.4(1) Users are reminded that NFPA 2112 provides certification to minimum thermal protective requirements. Garments can exceed the requirements of NFPA 2112. The result of the hazards analysis performed in accordance with 4.2.3 of NFPA 2113 should identify a possible range of thermal exposures, which should be considered when selecting appropriate protective clothing. [2113:A.4.3.1(1)]

The principal method used for evaluating the thermal protective characteristics of the fabric is the heat transfer performance (HTP) test, described in Annex B. Two different HTP ratings are provided from this test. “Spaced” HTP ratings are considered representative of those areas of the garment where air spaces exist between the garment and the wearer’s skin. “Contact” HTP ratings are considered representative of those areas of the garment where the garment fabric is in direct contact with the wearer’s skin. Consideration should be given to maximizing these values in relation to other garment fabric properties described in A.8.6.2.4(2) through A.8.6.2.4(8). Increasing HTP ratings can come at the expense of increased garment weight and reduced wearer comfort. [2113:A.4.3.1(1)]

Table A.8.4.6.3 Unscheduled Housekeeping

Accumulation Level	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.8.6.2.4(2) Fabrics used in the construction of flame-resistant garments have different physical characteristics. These characteristics can be based on the style of fabric construction (e.g., knit versus woven fabric) or other characteristics of the fabric such as its weight, thickness, and stiffness. Annex B provides a description of some of the physical characteristics of flame-resistant garment fabrics. [2113:A.4.3.1(2)]

A.8.6.2.4(3) Flame-resistant garments are generally constructed of a primary fabric or set of fabrics but also include other fabrics and components. NFPA 2112, addresses the performance of many of these components, but not all components. Emblems such as patches or logos are used to identify the organization or individual. Because emblems are usually constructed of non-flame-resistant materials (such as cotton or nylon), the overall area of the emblem should be minimized on the garment. For example, large company logos across the back of the garment should not be applied. A preferable approach when large logos or identifications are needed could be silk-screening with flame-resistant films. In addition, the use of several patches over the entire garment should be avoided. [2113:A.4.3.1(3)]

A.8.6.2.4(4) The end user's body can store a large static charge. It is imperative that organizations not rely on clothing static-dissipative properties in place of grounding or other practices to avoid static charge buildup. Friction between clothing layers or between clothing and other surfaces can generate static electricity of sufficient energy to ignite combustible atmospheres. For these reasons it is important to minimize the buildup of static electricity on flame-resistant garments in order to prevent the garments from becoming a source of ignition. Therefore, workers should be grounded before entering a high-risk area and should avoid removing garments while inside the high-risk area. [2113:A.4.3.1(4)]

At low humidity levels (less than 20 percent relative humidity), garments made from either natural fibers (such as cotton or wool) or synthetic fibers (such as aramids and rayon) that rely on water content to dissipate static electricity are not static dissipative. One approach to reduce the static of these garments is to use a static-dissipative treatment during laundering in keeping with the manufacturer's recommended care procedures. This treatment works by trapping water on the fabric to distribute the static charge through conductivity. The static-dissipative treatment needs to be added during each laundering cycle according to most manufacturers' instructions. Overdrying in the dryer should also be avoided to minimize static buildup. The organization should verify with the manufacturer that the static-dissipative treatment does not reduce the flame resistance or other properties of the garment. [2113:A.4.3.1(4)]

An alternative approach is to use garments made of inherently static-dissipative fibers or other equally efficient anti-static construction. These blended fibers dissipate static charges by induction and are effective regardless of the environmental conditions, where the relative humidity can be 20 percent or less. [2113:A.4.3.1(4)]

A.8.6.2.4(5) Flame-resistant garments are available in different types such as coveralls, shirts, trousers, jackets, gloves, shrouds/hoods/balaclavas, and rainwear. These garments can be constructed of single-layer or multi-layer fabrics. In addition, the garments can include different design features such as closures (zippers, snaps, or buttons) and pockets. The selection of the design type should consider the work environment, the

types of other clothing or equipment to be worn, and the tasks being performed by the wearer. [2113:A.4.3.1(5)]

A.8.6.2.4(6) The selection of the garment should take into consideration the working conditions of the end users wearing the garments. Conditions include the range of temperatures and relative humidities, the location of the work, and the tasks to be performed by the wearer. [2113:A.4.3.1(6)]

A.8.6.2.4(7) Several factors relate to fabric or garment comfort, including fabric weight and thickness, air permeability, water vapor transport, evaporative resistance, moisture regain, and wickability. Comfort assessment also has a subjective dimension that is not readily measured in a laboratory. Wear trials are recommended and often provide other useful information. [2113:A.4.3.1(7)]

A.8.6.2.4(8) Certain fabrics can be laundered, while others should be subjected to special cleaning procedures such as dry cleaning. The organization should consider the cleaning procedures associated with a particular fabric or garment type for its selection. In addition, the fabric's durability should also be a consideration for selection. [2113:A.4.3.1(8)]

A.8.6.2.6 At a minimum, the policy should address who is responsible for laundering, inspecting, repairing, and retiring garments. See also Section 6.1 of 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.8.6.3.1 This section does not include an incidental amount of elastic used in nonmelting fabric, underwear, or socks.

A.8.6.3.2 See also Section 5.1 of NFPA 2113.

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 deflagration 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 deflagration vents and other explosion protection systems are found in NFPA 68 and NFPA 69, respectively.

A.8.7.2 Inspection and maintenance of potential ignition sources means inspection and maintenance of equipment that could introduce a potential ignition source, such as bearings and other points of friction or mechanical sparks, as discussed in Section 9.6. Inspecting housekeeping equipment includes equipment such as portable vacuums.

A.8.7.2(4) International guideline BS EN 1127-1, *Explosive atmospheres, explosion prevention and protection — Basic concepts and methodology*, distinguishes the following 13 different types of ignition sources. This ignition source list is well suited to inform DHAs and incident investigations.

- (1) Hot surfaces (e.g., heated equipment, friction on shafts and bearings, process equipment, and connecting piping)
- (2) Flames and hot gases, including hot particles (e.g., hot work, open flames, fuel fired equipment, and burning embers)
- (3) Mechanically generated sparks (e.g., impact- and friction-generated sparks)
- (4) Electric apparatus (e.g., “on/off” switches)
- (5) Stray electric currents and cathodic corrosion protection (e.g., welding equipment)
- (6) Static electricity (e.g., propagating brush, brush, cone discharges, and static shock)
- (7) Lightning
- (8) Radio frequency (e.g., radio transmissions, welding, cutting, and heating applications)
- (9) Electromagnetic waves (e.g., rotating equipment generates fields, light waves, and lasers)
- (10) Ionizing radiation (e.g., X-rays and gamma rays)
- (11) Ultrasonic (e.g., SONAR, gauging devices, and spray nozzles)
- (12) Adiabatic compression and shock waves (e.g., piston action)
- (13) Exothermic reactions, including self-ignition of dust (e.g., wet grain decomposition)

In addition, FM Property Loss Prevention Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire*, provides losses as a function of ignition source. See Table A.8.7.2(4).

A.8.7.2(6) 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 Center for Chemical Process Safety, *Guidelines for Safe Automation of Chemical Processes*.

A.8.7.2(8) Examples of these devices include drawer type, roller, belt, elutriator, screens, or magnets.

Table A.8.7.2(4) Losses by Cause (Ignition Source)

Cause Type	Number of Losses	Gross Loss in Millions of Dollars (US)
Friction	50	64.5
Spark	38	24
Chemical action	16	25
Hot work	13	2.7
Burner flame	10	151
Electricity	6	4
Static electricity	6	4
Overheating	4	2.4
Hot surface	2	2
Unknown/no data	21	13.7
Total	166	284

Source: FM Property Loss Prevention Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire*, May 2008–2017.

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.

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.

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.8.9.3 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 location of smoking and nonsmoking areas. The owner/operator does not necessarily need to provide the training to the contractor.

A.8.9.3.2 For example, a company might use contract employees to conduct some process operations. The training provided to the contractor employees should be equivalent to the training that the company would provide to similarly situated company employees were they to be performing the operations.

A.8.9.3.3 In addition to the combustible dust or particulate solid fire, flash 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 The retroactivity of Chapter 8 is not intended to require investigation of incidents that occurred prior to the adoption of this standard.

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.

See the CCPS *Guidelines for Investigating Process Safety Incidents* for additional guidance on incident investigation.

A.8.10.2 In addition to investigation of fires, flash fires, and explosions, it is also a good practice to investigate near misses (events that could have resulted in fires, flash 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. 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.8.10.4 Incident reports should include the following information:

- (1) Date of the incident
- (2) Location of the incident and equipment/process involved

- (3) Description of the incident, contributing factors, and the suspected cause
- (4) Operation of automatic/manual fire protection systems and emergency response
- (5) Any recommendations and corrective actions taken or to be taken to prevent a reoccurrence

A.8.10.6 The term *affected personnel* is intended to include members of employee organizations such as safety committees and employee representatives of various types.

The incident report should also be reviewed with appropriate management personnel and retained on file for future reference. Incident reports are useful in support of the periodic DHA required by 7.1.4. The owner/operator should consider retaining the incident investigation reports for at least 5 years to be consistent with the DHA review schedule.

The owner/operator should consider sharing relevant learnings with other facilities within the company.

A.8.11 See CCPS *Guidelines for the Management of Change for Process Safety* for additional guidance on management of change.

A.8.11.1 Changes to procedures, processes, resources, safety systems, and equipment, including equipment from suppliers, can have a significant impact on facility and operational safety. Change can include something as seemingly innocuous as sourcing process materials from a different manufacturer, the same raw material manufacturer using new methods to produce the materials, or changes in formulation. These changes from a supplier's end can impact the characteristics of the materials and effect process operation and safety. Potentially significant changes include changes to organizational structure that could impact the organization's ability to safely manage the facility and its operations. For reference, see the documentation form in ANSI/AIHA Z10, *Occupational Health and Safety Management Systems*.

Section 8.11 requires the documentation and implementation of a system to evaluate and control proposed changes to prevent negative impacts on safety. Individuals involved in the evaluation of proposed changes could represent functions such as process operations, maintenance, engineering, purchasing, and others as deemed necessary.

Changes that can introduce new hazards or increase existing hazards and warrant a management of change review per Section 8.11 include, but are not limited to, the following:

- (1) Installation of new process equipment
- (2) Modification of existing process equipment
- (3) Revision to operating conditions or procedures
- (4) Use of a new material in the process
- (5) Removal or disabling of existing safety systems
- (6) Reducing the number of operators on each shift

The potential significance of the changes on process material characteristics should be considered. Process materials might need to be sampled and analyzed in accordance with Chapter 5 to determine if the combustibility and explosibility characteristics that served as the design basis for safety systems have been adversely affected.

A.8.11.2(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.8.11.2(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.8.11.3 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 8.11.2, 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, a safety data sheet (SDS). 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.8.11.4 See A.8.13.1(5) for examples of such documentation.

A.8.12 An ORR is intended to ensure that, before start-up, a facility is mechanically ready, related management systems (e.g., procedures, training, and inspection, testing, and preventive maintenance programs) have been updated, and personnel are prepared to safely start-up and operate the facility.

A.8.12.1 The owner/operator should consider extending the coverage of the ORR program to include other types of shutdowns such as, but not limited to, emergency shutdowns and precautionary shutdowns in anticipation of external events such as severe storms. The intent of the ORR program is that any facility that has been shut down will receive a review, the scope of which is commensurate with the nature and duration of the shutdown, before the facility is returned to service. See the CCPS *Guidelines for Risk Based Process Safety*.

A.8.12.1(5) An example of such a shutdown would be a facility that has been idled for an extended period (e.g., months or longer) for business reasons. Such a facility might be returned to service with little or no modification. However, changes in associated facilities, changes in feed specifications, changes in risk control requirements, potential degradation of equipment, and so forth, might warrant a detailed review, including a DHA update, before the facility is returned to service. Another example would be facilities that have been shut down for major maintenance activities.

A.8.12.2 The lists in 8.12.2 provide the basic requirements for the ORR for the various types of changes. Additional factors could be relevant to particular start-ups. The owner/operator

should carefully assess the nature and duration of the shutdown and determine if additional confirmations are warranted for a safe start-up. Table A.8.12.2 provides a graphical representation of the lists.

A.8.12.3 The extent of the ORR documentation should consider the nature and duration of the shutdown. For a maintenance shutdown the documentation could be signatures on the work order after a joint inspection by maintenance and operations. For a routine start-up of a facility that has been shut down as part of normal operations the documentation could be a completed start-up procedure. For new facilities, modified facilities, and facilities that are to start up after an extended outage, the documentation would likely be more extensive, incorporating one or more detailed checklists. To avoid making the documentation task burdensome, 8.13.1(7) only requires retention of documentation for these more detailed ORRs.

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(4) Resolution could include documented acceptance or rejection of a recommendation, schedule for timely implementation of accepted recommendations, and documentation of final implementation.

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(9) 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, *Occupational Health and Safety Management Systems*. The OHSMS ensures that facility employees and their authorized representatives are involved, informed, and trained on all aspects of health associated with

Table A.8.12.2 Operational Readiness Review Requirements for Types of Shutdowns

Required Review Confirmations	For Shutdowns Described In				
	8.12.2(1)	8.12.2(2)	8.12.2(3)	8.12.2(4)	8.12.2(5)
Construction and equipment are in accordance with design specifications.	X	X	X		X
A DHA has been performed in conformance with Chapter 7, and action items have been resolved or implemented before startup.	X				X
Accurate, up-to-date safety, operating (including startup), maintenance, and emergency procedures are in place.	X	X			X
Accurate, up-to-date startup procedures are in place.			X	X	
Affected personnel have been trained on relevant procedures.	X	X			X
A management of change review has been conducted in conformance with Section 8.11, and action items have been resolved or implemented before startup.		X			
A joint inspection by maintenance and operations personnel has verified that the maintenance has been correctly completed.			X		
A walk-through inspection has verified that the facility is ready for start-up.				X	
Inspection and testing of safety systems and equipment have been conducted.	X	X			X

their work, including emergency arrangements. Employee participation includes items such as, but not limited to, the following:

- (1) Involving facility 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 facility employees and their representatives share are received, considered, and responded to

- (11) Facility 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 facility 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.8.10.6.)

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 deflagration 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 combustible dust or particulate solid fire, flash fire, or 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.9.2.1 A means to determine protection requirements can be based on a risk assessment, with consideration given to the size of the equipment, likelihood and consequences of fires, flash fires, or explosions, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections

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 deflagration 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.

are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with a variation of the prescribed protective measures. For example, a bearing that is external to a piece of equipment could be capable of being an ignition source, but due to its location, it is determined to pose a tolerable risk of fire or explosion and, therefore, does not require temperature monitoring.

A.9.3.1 It is preferable for buildings that handle combustible dust to be of either Type I or II construction, as defined by NFPA 220.

A.9.3.2.1 Chapter 7 provides the process to determine where and whether a dust or particulate solid fire, flash fire, or explosion hazard exists. Section 9.3 is not intended to cover process equipment such as bins and silos.

A.9.3.2.2 Deflagration venting is provided to prevent damage to portions of the building surrounding the vented compartment. Deflagration venting for a compartment cannot be expected to provide protection for the occupants of that compartment.

The term *deflagration venting* is used in 9.3.2.2 because not all explosions can be effectively prevented by venting, and deflagration venting is the only type of explosion venting that can be effective for combustible dust explosions. The rate of pressure rise in a deflagration allows a vent closure to open before destructive dust explosion pressures develop in the compartment. Hence, the term *deflagration venting* is used throughout this document. Deflagration venting can limit the pressures developed in the building compartment but will not prevent injuries to personnel in the compartment at the time of the deflagration.

Historically, the term *explosion venting* has been used.

A.9.3.2.2.2 Venting of a deflagration should be to a safe area where personnel and equipment are not normally present so not to pose a hazard to additional personnel or property assets. This area should be determined per 9.4.4.2 of this standard and 6.6.2 of NFPA 68 and communicated by markings or signage or communicated to affected personnel, including contractors, and considered when establishing temporary work areas, temporary storage, or addition of new structures or equipment.

A.9.3.3.2 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.

A.9.3.4.1 To the extent feasible and practical from a cost and sanitation standpoint, horizontal surfaces should be minimized to prevent accumulation of dust. Horizontal surfaces that can benefit from a sloped cover include girders, beams, ledges, and equipment tops. Overhead steel I-beams and similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. The additional weight of the box enclosures should be considered in the structural design. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning. One option based on clean design concepts is to construct the building walls so that the structural supports, electrical conduit, and so forth are on the exterior side of the building walls; therefore, the interior building compartment walls are smooth and less likely to collect fugitive dust.

A.9.3.4.2 Inaccessible areas can be enclosed areas too small to allow for cleaning and removal of dust accumulations. These areas should be sealed in such a way to prevent openings through which combustible dusts can enter. Examples could include where penetrations or other construction features have left spaces where dust could enter (e.g., a hollow wall or spaces between equipment and walls).

A.9.3.4.3 The space above suspended ceilings is an example of a space that is difficult to access for routine housekeeping. Periodic inspection of such spaces is necessary to ensure accumulations do not result in a fire, flash fire, or explosion hazard area.

A.9.3.5.3.1 A building could be considered as a single combustible dust hazard area, or as a collection of smaller, separated combustible dust hazard areas. When the owner/operator chooses to consider the building as a single area, then the hazards 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 hazards 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.9.3.5.3.2 Separation distance is the distance between the outer perimeter of a primary dust accumulation area and the outer perimeter of a second dust accumulation area. Separation distance evaluations should include the area and volume of the primary dust accumulation area as well as the building or room configuration.

A.9.3.5.3.3 When separation is used in accordance with Chapter 7, the minimum 35 ft separation is consistent with that required for hot work activities and could be expanded based on the engineering evaluation in 9.3.5.3.2.

A.9.3.5.3.6 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. (0.025 cm) 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.9.3.5.4.2 Detachment distance is the radial distance between nearest points of two unconnected adjacent buildings.

A.9.4.1.1 The system information and documentation should include the following:

- (1) System design specifications
- (2) System installation specifications
- (3) Equipment specifications
- (4) Operational description

- (5) Material combustibility and explosibility information
- (6) Fire and explosion protection system specifications and design
- (7) System mechanical and electrical drawings
- (8) System controls and specifications

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

A.9.4.1.2 Changing existing equipment or systems can significantly alter the ability of the system to provide the original design performance. An analysis of any proposed changes should be done to assure the equipment or system will still be able to perform as required to meet safety and operational requirements.

A.9.4.2.2 The goal is first to try and contain the dust inside equipment, second capture any dust that escapes the equipment, and then clean any remaining dust.

A.9.4.3 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 significantly lower flame and overpressure risks. However, that does not mean there is not a flame and overpressure risk present. Risk assessment should be used to determine the level of risk involved and the correct means to minimize that risk.

A.9.4.3.1.1 The minimum gas velocity to transport materials varies considerably due to the material characteristics, conveying rates, conveying distances, and other factors. If the velocity falls below the minimum requirement, plugging and other upset conditions could occur and lead to an unsafe operating condition. Typically the minimum gas velocities are established by testing or are based on existing data from the system designer or vendor.

Dust collection systems and centralized vacuum cleaning systems handling combustible dusts usually use branched duct networks with multiple pickup points and variable material loading. In contrast, dilute phase and dense phase pneumatic conveying systems are typically linear systems with controlled infeed and consistent material loading. Dust collection systems for combustible dusts represent a significant increase in deflagration risk compared with most pneumatic conveying systems. A properly designed system is critical to minimizing that risk. For guidance on determining proper dust collection system design, refer to the ACGIH publication, *Industrial Ventilation: A Manual of Recommended Practice*.

According to *Industrial Ventilation: A Manual of Recommended Practice*, the duct air velocity can range from a minimum of 3500 fpm (18 m/sec) to significantly higher levels. However, that document is for all dusts, including noncombustible dusts. A velocity of 4000 fpm (20 m/sec) is recommended as a minimum value for the conveying of combustible dusts. Also, some combustible dusts have material characteristics (e.g., cohesiveness, adhesiveness, particle shape and size, particle density) that require significantly higher duct velocities to minimize the possibility of accumulations in the ducts.

A.9.4.3.1.2 The importance of locating the control equipment so that personnel operating the system are safe can be illustrated by the following conditions:

- (1) Where there is no explosion protection for the dust collector, the personnel operating the system 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.
- (3) Where flameless vents are provided, thermal effects of the vent discharge should be taken into consideration.

To address the above situations, it is possible to provide blast protection for personnel who must be in the danger zone.

Control equipment might include any device to which people interact that places personnel potentially in harm's way, exposing them to the effects of an explosion in the AMS.

A.9.4.3.1.4 The requirements in 9.4.3.1.4 are applicable to dilute phase pneumatic conveying systems. Dense phase systems require a separate analysis.

A.9.4.3.1.4.2 Some chemical and plastic dusts release residual flammable vapors such as residual solvents, monomers, or resin additives. These vapors can be released from the material during handling or storage. Design of the system should be based on a minimum airflow sufficient to keep the concentration of the particular flammable vapor in the airstream below 25 percent of the LFL of the vapor.

A.9.4.3.1.5.4 Adjustment of any airflow control valve will influence the flow through the entire system. Therefore, once manually adjusted valves are properly positioned for flow, they must be secured to prevent inadvertent movement.

A.9.4.3.2 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.9.4.3.2.1 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 and explosion protection of the process and equipment systems.

A.9.4.3.2.2 Examples of pressure vessel or process piping codes used in the US are Section VIII of the ASME *Boiler and Pressure Vessel Code*, or ASME B31.3, *Process Piping*. 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.9.4.3.2.3 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 fire and explosion hazards do exist, it is typically necessary to provide the proper protection for fire and explosions in the filter receiver (AMS) and propagation through the system.

A.9.4.3.3 Dust collection systems for combustible dusts represent a significant increase in fire and explosion 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 the ACGIH publication, *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.9.4.3.3.1 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 publication, *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.9.4.3.3.2 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.9.4.3.3.3 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 airflows 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.9.4.3.3.4 Installation of branch lines for additional dust sources to an existing dust collection system without compensating for that change will result in lower air volumes and duct velocities for the existing portions of the system. Failing to provide additional system performance can result in a system performing below the minimum required velocities for keeping the ducts free from material accumulations.

A.9.4.3.3.5 The intent of this requirement is to minimize the potential for a flame, spark, or other hot material propagating to an AMS or interconnected ductwork where a fire or explosion hazard could exist.

Examples of methods to control propagation of flames, sparks, or hot material sources include but are not limited to the following:

- (1) A listed spark detection and extinguishing system
- (2) A listed spark detection system actuating a high-speed abort gate

The protections above are not explosion isolation systems. Explosion protection requirements on any interconnected equipment need to be evaluated in accordance with Section 9.8.

A.9.4.3.3.6 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 Chapter 22 for metal dust collection.

A.9.4.3.3.7 The majority of dust collection systems use centrifugal fans for inducing the airflow through the system. Various models are available that will provide the performance characteristics required. Care must be taken to consider the worst-case situation, when the filters are nearly blinded or the scrubber is at maximum differential, as well as the situation where the system is new during start-up.

A.9.4.3.3.8 Where combustible dust emissions are likely, they should be managed with a dust collection system. The operator shall not use the HVAC system to capture dust emissions or to prevent dust accumulations. It is recognized that dust collection systems might not capture 100 percent of the dusts released from localized sources. It is not the intent of this requirement to prohibit the use of HVAC systems where incidental amounts of airborne dust are present and the HVAC system has been designed to address this hazard. Special attention should be given to areas where low air velocity exists and dust can settle out, such as the return air plenum.

A.9.4.3.4 A centralized vacuum cleaning system represents a significant fire or explosion 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 fires and explosions, 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.9.4.3.4.1 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.9.4.3.4.2 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.9.4.3.4.4 Ignition-sensitive materials typically have an MIE of 30 mJ or less. The attachment between the tool and hose provides the bonding path for electrostatic charge dissipation through the hose, and ultimately to ground through the central vacuum system connection.

A.9.4.3.4.5 The creation of static electrical charges is a risk factor that can be minimized through the use of grounded conductive or static dissipative vacuum cleaning tools and hoses. The bonding connections between the cleaning tool, hose, and the grounded central vacuum system attachment point create the path to ground for electrostatic charges generated during cleaning. The use of nonconductive couplings between hose sections can impair the dissipation of charges and lead to spark discharges. Some vacuum hoses use a metallic reinforcing wire that is connected to the cuffs on both ends of the hose as the means of bonding the tool to the central vacuum system attachment point. In these cases, a break in the wire can also lead to spark discharges. Refer to 9.6.6.1.3 and 9.6.6.1.4 for additional requirements for bonding and grounding with flexible connectors. There is a higher risk of ignition 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 Chapter 22.

A.9.4.4.1.2 The AMS should not be used as a combustible dust storage device due to the potential of bridging filling the unit to the point it will not function, possible inhibiting of the material discharge due to bridging and plugging of the discharge, and possible self-heating of some type of dusts. In addition, overfilling can interfere with the function of explosion prevention/protection equipment. A rotary airlock valve or a rotary airlock valve and screw conveyor combination can be used to provide for continuous discharge of the separated dusts; alternatively, a slide valve can be used where dust loadings are light, provided that the material is removed frequently enough to prevent bridging and plugging. The container below the rotary valve or other continuous discharge device should be designed for the type of material collected and the typical rates of material collected and to minimize the creation of aerated dusts during the discharge of the material from the AMS into the container. It is also important to maintain regular emptying or replacement of the collected material container to minimize the risk of overfilling.

A.9.4.4.2 See NFPA 68 for guidance on calculating the dirty side volume.

A.9.4.4.6.2 This section is in reference to closed-loop pneumatic conveying systems.

A.9.4.4.6.3 Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as

described in the ACGIH publication, *Industrial Ventilation: A Manual of Recommended Practice*, should be followed.

When “clean air” is being returned to the facility interior, it is important to understand that the return air might contain some residual dust depending on the particulate capture effectiveness of AMS. Note also the need for evaluation of required oxygen level in return gas stream as well as possibility of toxicity of gas to personnel. Usually the filter media in a dust collector traps the large particles, but there might be very fine material that manages to get through the filter media and accumulates downstream within the clean air plenum and return air duct. A routine maintenance program is necessary to ensure that the clean air side of the dust collection system remains sufficiently clean to achieve the safety objectives of the standard. The use of HEPA secondary filters or particulate monitors can often reduce the frequency of inspection but should not be expected to eliminate it.

A.9.4.4.6.3(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.9.4.4.6.3(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.

A.9.4.4.7.4 Pockets of accumulated dusts could become airborne, augmenting the fuel concentration in the event of a pressure surge or deflagration. In addition, internal areas where dust could accumulate inside an AMS could create a risk of ignition of self-heating dusts.

A.9.4.4.7.5 An AMS can have a hopper attached to its filter housing. In other cases, a filter vent can be directly attached to a bin or silo without a hopper. In the arrangement with a hopper, flow difficulties, such as bridging and ratholing, could occur during accumulation of the particulate solids in the hopper section. These flow obstructions can create reduced discharge efficiencies, as well as caking problems. Achieving reliable flow from an AMS hopper requires two key design considerations, namely sufficiently steep slope of the hopper walls and low enough coefficient of sliding friction between the particulate and the wall material of construction to allow particles to slide against it based on gravity flow. Ideally, the hopper and feeder/valve arrangement are operated in a manner to prevent particulate accumulation in the hopper, thereby avoiding flow obstructions. However, if accumulation occurs, proven engineering methods are available to prevent or solve the issues of flow obstructions. Another consideration is to size the outlet to be sufficiently large enough to achieve the required flow rate to the downstream process. In some limited cases, flow aids like air cannons, air sweeps, or high frequency vibrators or thumpers could be required to supplement gravity flow hopper solutions. The hopper should also be designed/operated to safely handle the maximum throughput rate of the dust collection system. Level detectors should be installed with a control system input to ensure the dust collection system is shut down or alarmed to indicate insufficient capacity in the hopper.

Accumulations or air leakage in the bottom of a cyclone can result in a reduction of the efficiency of the cyclone to separate

material from the air stream, leading to additional material flowing through the outlet air stream.

A.9.4.4.7.6 An example of how this can be accomplished is with a mechanical sweep or an air sweep.

A.9.4.4.7.7(3) The doors are typically bonded through the hinge or attachment points and grounded through the piece of equipment.

A.9.4.4.7.7(4) See NFPA 68. If a dust collector door is designed to be used as a vent, the access door should be marked that it is an deflagration vent with the associated hazards.

A.9.4.5.2 An explosion hazard might exist when combustible dust, gas, or mist is conveyed through system ductwork. An example of hazard would be fan failure due to bad bearings or the impeller becoming unbalanced, creating an ignition source. When possible, the AMD should be located such that the combustible materials are not passed through it. When combustible materials must be conveyed through the AMD, the AMD should be designed to handle the dust or mist, and appropriate spark-resistant construction should be used, or spark detection or similar protection systems should be provided downstream from the AMD discharge.

A.9.4.5.3 These systems include pneumatic conveying systems that require relay (booster) fans and product dryers where the fan is an integral part of the dryer.

A.9.4.5.4 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.

A.9.4.6.2 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.

A.9.4.6.3 Isolation devices in accordance with 9.8.3 are provided to prevent propagation of flames or pressure between connected equipment. According to 9.8.3, additional protection is indicated when the integrity of a physical barrier could be breached through ductwork failure caused by a of flames or pressure 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.

A.9.4.6.4.4 The doors are typically bonded through the hinge or attachment points and grounded through the piece of equipment.

A.9.4.7 This section refers to sight glasses used in pneumatic conveying, dust collection, centralized vacuum cleaning, and similar transfer systems. This section is not applicable to sight glasses or viewing windows used for level control of hoppers or similar applications.

A.9.4.9.1.2 Shipping 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 explosion protection.

A.9.4.9.2 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. The contents of the bulk storage enclosure could add to the fire load if the bulk storage enclosure wall is breached, and this should be considered when evaluating the fire load.

A.9.4.9.3.2(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.

A.9.4.9.4 Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the number of surfaces where dust can accumulate.

A.9.4.9.5(3) The doors are typically bonded through the hinge or attachment points and grounded through the piece of equipment.

A.9.4.10 Size reduction machinery includes equipment such as mills, grinders, and pulverizers. grounded through the piece of equipment.

A.9.4.11 Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices.

A.9.4.12.2.3 The hazards due to over-pressurization in addition to potential rupture include elevated equipment temperatures. Even below 15 psi, a deadheaded system might generate enough heat to produce temperatures that might ignite a combustible dust.

A.9.4.12.2.4 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.9.4.17 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.

A.9.4.17.1.1.1 Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as described in Chapter 7 of the ACGIH publication, *Industrial Ventilation: A Manual of Recommended Practice*, should be followed.

A.9.4.17.1.1.1(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.9.4.17.1.1.1(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.

A.9.4.17.1.2 Possible control measures include but are not limited to dust collection, explosion protection, fire protection, monitoring, and detection and extinguish systems.

A.9.4.17.1.4.1 Cleaning methods and frequency will differ depending on the type of dryer. Effectiveness typically relates to depth and extent of the dust accumulation. Frequency can be adjusted based on the level and rate of accumulation. The ignition temperature of a dust layer will vary based on the depth and moisture content of the solids on the dryer surfaces. Material self-heating characteristics at drying temperatures might need to be considered. Excessive accumulations of dust in a dryer could form an ignition source or an explosive dust cloud if they were to break free and be suspended in the dryer.

A.9.4.17.1.7 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 US 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 US Bureau of Mines test procedure given in Miron and Lazzara's report, "Hot Surface Ignition Temperatures of Dust Layers."

A.9.4.17.1.8 The operating control loop is intended for process temperature modulation. The excess temperature-limit safety interlock is a separate control method to shut down the heat source due to excessive temperature. Refer to NFPA 86 for additional information.

A.9.5.1.1 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.

The quantity of hazardous dust, the properties of the hazardous dust, and the equipment location (indoor or outdoor) all affect the risk associated with the fugitive dust. In some instances, normal housekeeping can be sufficient to reduce any risks. A DHA can provide further guidance.

A.9.5.2 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.

A.9.5.3 These devices are used to continuously prevent dust from accumulating on hard-to-access 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.

As an example, these systems have been successfully used for facilities with high ceilings where light, easily entrained dusts or fibers are handled.

A.9.5.3.8 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.

A.9.6.1 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 9.6.1 means that a plan should be established to achieve compliance within a reasonable time frame.

A.9.6.3.2 This section does not apply to electrical systems.

Examples of exposed surfaces include compressors; steam, water, or process piping; ducts; and process equipment.

Fire losses have occurred where steam piping was identified as the ignition source. For example, for wood dust deposits, it is possible that prolonged exposure to elevated temperatures could produce cellulose pyrolysis products that can have lower ignition temperatures than those normally associated with wood. Therefore, in permitting maximum surface temperatures above 100°C (212°F) (the minimum steam temperature), it is assumed that appropriate personnel safety measures are in place and that a rigid housekeeping program exists to keep dust accumulations under control. Equipment surfaces in hard-to-access locations that will collect dust and are likely to be cleaned less frequently should be insulated to keep the maximum surface temperature below 100°C (212°F).

Similarly, the ignition temperature of a layer of dust on hot surfaces could decrease over time if the dust dehydrates or carbonizes. For organic dusts that can dehydrate or carbonize, the temperature should not exceed the lower of the ignition temperature or 329°F (165°C). The ignition temperatures for many materials are shown in NFPA 499.

Dust layer and dust cloud ignition temperatures should be determined by ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*, ASTM E1491, *Standard Test Method for Minimum Autoignition Temperature of Dust Clouds*, ISO/IEC/UL 80079-20-2, *Explosive atmospheres — Part 20-2: Material characteristics — Combustible dusts test methods*, or other recognized test methods.

The dust layer thickness used in ASTM E2021 is nominally 0.5 in. (1.27 cm). The minimum ignition temperature typically

decreases with increasing layer thickness, and testing up to maximum layer thickness to be expected on external surfaces is recommended.

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; however, this is not universally true (*see NFPA 499*).

A.9.6.4.2 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.9.6.4.4 The risk assessment should include the potential for propagation of a fire, flash fire, or explosion from an unmonitored unit.

A.9.6.5.1 The best method to eliminate the need for hazardous (classified) locations is to prevent the release of dust from equipment. The next best method to eliminate the need for hazardous (classified) locations 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 a hazardous (classified) location. NFPA 499 can be used for guidance to supplement the criteria in NFPA 70. This guidance depends on a determination of the combustibility of dust in a particular area, the ignitability properties of the dust, and the nature of possible dust cloud formation and dust layer accumulations within and outside the electrical equipment near the dusts. NFPA 499 is a good source for guidance on identifying hazardous (classified) locations.

The user of this document should be aware that the dust layer accumulation criteria in Articles 500 and 506 of NFPA 70 and NFPA 499 are intended to address electrical ignition hazards due to overheating or shorting of electrical equipment. However, the threshold housekeeping dust accumulation limit defined in this standard is based on a dust flash fire or dust explosion hazard. These differing criteria can lead to different layer depth allowances. It is possible that even where electrically classified equipment is installed, the area can still be considered a fire, flash fire, or explosion hazard area.

A.9.6.5.1.1 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 hazardous (classified) locations. Knowledge of hazardous (classified) locations gives anyone over the lifetime of the facility the awareness of immediate hazards within the facility.

A.9.6.5.3 The intent of these preventative maintenance programs should be to inspect the electrical enclosures for dust intrusion and not for dust accumulations on the exterior of the electrical enclosures. NFPA 70B contains recommendations on the development of an effective electrical equipment maintenance program. Articles 502 and 506 of *NFPA 70* contain 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.

A.9.6.5.4 Intrinsic safety and nonincendive circuits are defined for use in atmospheric oxygen at concentrations not greater than 21 percent as stated in the ANSI standards used to certify the equipment. Greater than 21 percent oxygen concentration or a more sensitive oxidizing medium would greatly lower the safety factor on these circuits. Dust exclusion types of protection, such as dust ignitionproof, dusttight, purged and pressurized, encapsulation, and hermetically sealed, remain effective, regardless of the process-specific oxidizing medium.

A.9.6.6 Several types of electrostatic discharges are capable of igniting combustible dusts and hybrid mixtures. The requirements in 9.6.6 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 a 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 NFPA 652, 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*.

A.9.6.6.1.2(1) This requirement is intended to prevent ignition of hybrid mixtures or flammable gas/vapor atmospheres by brush discharges from nonconductive surfaces.

A.9.6.6.1.2(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.

A.9.6.6.1.2(3) This requirement is intended to prevent ignition of combustible dusts by capacitive sparks from isolated process equipment.

A.9.6.6.1.2(4) This requirement is intended to prevent ignition of combustible dusts by propagating brush discharges. Pneumatic conveying and milling are examples of process operations that can generate high surface charging.

A.9.6.6.1.3 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.9.6.6.1.3 for illustrations of bonding and grounding principles.

A.9.6.6.1.4 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

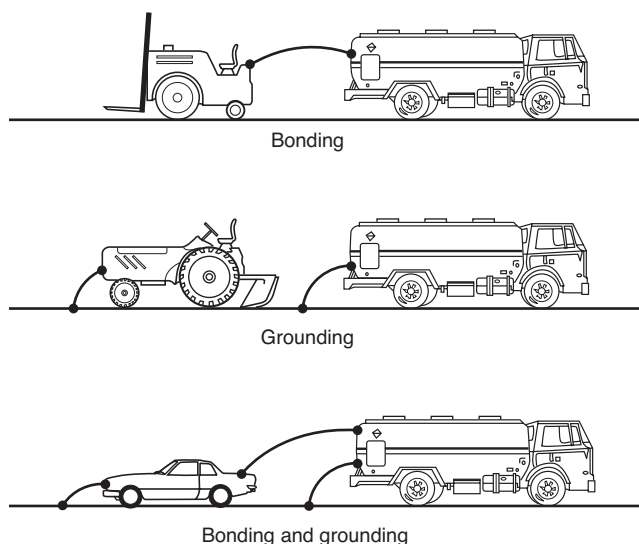


FIGURE A.9.6.6.1.3 Bonding and Grounding.

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.

A.9.6.6.1.4.1 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.9.6.6.1.4.2 Flexible connectors can produce electrostatic ignition hazards in multiple ways. Where they connect two conductive objects, flexible connectors can introduce a resistance to bonding and grounding of the objects on either end, creating the potential for capacitive spark discharges. This hazard is typically addressed through the use of a dedicated bonding jumper or by connecting a metallic spiral reinforcement wire to the couplings on both ends of the flexible connector. Even where all conductive objects are bonded and grounded, flexible connectors can create propagating brush discharges through the connector itself. For a propagating brush discharge to occur, a voltage in excess of 4 kV must accumulate on the surface of the connector. Such a voltage can be generated when conveying dusts and particulate solids. The 10^6 ohms limit is based on a streaming current calculation. Per Glor (1988), the charge to mass ratio for resistive particulate

solids is on the order of 1×10^{-4} C/kg. With a conveying rate on the order of 22 lb/sec (10 kg/sec) (see A.9.6.6.2), the streaming current would be 10^{-3} C/sec (amps). At this current level, the voltage that could be generated by a resistance of 10^6 ohms would be 1 kV, which is low enough to prevent propagating brush discharges from occurring. The streaming current calculation method could be used to support an alternate end-to-end resistance threshold as part of a risk assessment for a specific conveying application.

A.9.6.6.1.4.3 The resistance limit of 10^8 ohms for gravity and mechanical conveying is less stringent than the limit for pneumatic conveying, dust collection, and vacuum cleaning due to the lower charge generation rates in gravity and mechanical conveying.

A.9.6.6.1.4.4 Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic discharge in industrial applications, are widely accepted to be capable of producing effective energies on the order of 1000 mJ. However, high charging applications involving large surface areas are theoretically capable of creating propagating brush discharges with energies exceeding 1000 mJ. Subsection 9.6.6.1.4.4 establishes a limit of 2000 mJ to account for such instances and allow for commercially available testing to determine if a dust MIE is greater than 2000 mJ. While this guidance is expected to be appropriate for most industrial applications, special care should always be taken to evaluate the process as part of the DHA to verify that insulative flexible connectors do not present an ignition hazard.

A.9.6.6.2 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).

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

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.

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

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.

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.

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 kg/hr to 5000 kg/hr (0.56 kg/sec to 1.4 kg/sec). For particles with diameters larger than 0.8 mm, he recommends maximum filling rates of 25,000 kg/hr to 30,000 kg/hr (6.9 kg/sec to 8.3 kg/sec).

A.9.6.6.3 NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive or static dissipative flooring and static dissipative 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 nonconductive residues do not interfere with continuity.

A.9.6.6.3.1 The user should expect that activities such as pouring, unloading, and transferring dusts can lead to the development of an ignitable atmosphere above the settled material in the receiving vessel.

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

A.9.6.6.3.2(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.9.6.6.4 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.9.6.6.4.1 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.

A.9.6.6.4.2 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.

A.9.6.6.4.2.2 For this application, conductive particulate solids typically are those materials having bulk resistivity less than 10^6 ohm-m.

A.9.6.6.4.3 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.

A.9.6.6.4.4 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.

A.9.6.6.4.5 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.

A.9.6.6.4.5.1 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, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance*,

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.

A.9.6.6.4.6 Table A.9.6.6.4.6 and Figure A.9.6.6.4.6 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. While Table A.9.6.6.4.6 indicates division locations, equivalent zone locations are also included. Class I, Division Group C/D is equivalent to Zone Group IIA/IIB. Class II, Division 1 and 2 is equivalent to Zone 20/21/22. 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, *Electrostatics — Part 4-4: Standard test methods for specific applications — Electrostatic classification of flexible intermediate bulk containers (FIBC)*.

A.9.6.6.4.6.3 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, *Electrostatics — Part 4-4: Standard test methods for specific applications — Electrostatic classification of flexible intermediate bulk containers (FIBC)*, and Table 20 of IEC TS 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance*.

Type L1 liners are made from materials with surface resistivity on at least one surface of less than 10^7 ohms and, where necessary, a breakdown voltage through the material less than 4

kV. They should be used only with Type C FIBCs, and the liner should be electrically bonded to the conductive elements of the FIBCs.

Type L2 liners are made from materials with surface resistivity on at least one surface between 10^9 ohms and 10^{12} ohms and a breakdown voltage through the material less than 4 kV. They should be used with Type B, C, or D FIBCs. When used with Type D FIBCs, the combination of FIBCs and liner should be tested together.

Type L3 liners are made from materials with surface resistivity of greater than 10^{12} ohms and a breakdown voltage through the material less than 4 kV. They should be used only with Type B FIBCs.

Type A FIBCs have no specific requirements for liners, because Type A FIBCs are not appropriate for use in hazardous atmospheres regardless of liner type.

Users should consult an expert or the latest edition of IEC TS 60079-32-1 to validate proper liner selection.

A.9.6.6.4.7 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 9.6.6.4. 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.

A.9.6.6.5.1 Conductive containers are generally made from either metal or carbon-filled plastic having a volume resistivity less than 10^6 ohm-m.

A.9.6.6.5.2 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.9.6.7.1 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. The 35 ft (11 m) radius can be expanded where conditions warrant.

Table A.9.6.6.4.6 Use of Different Types of FIBCs

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

Notes:

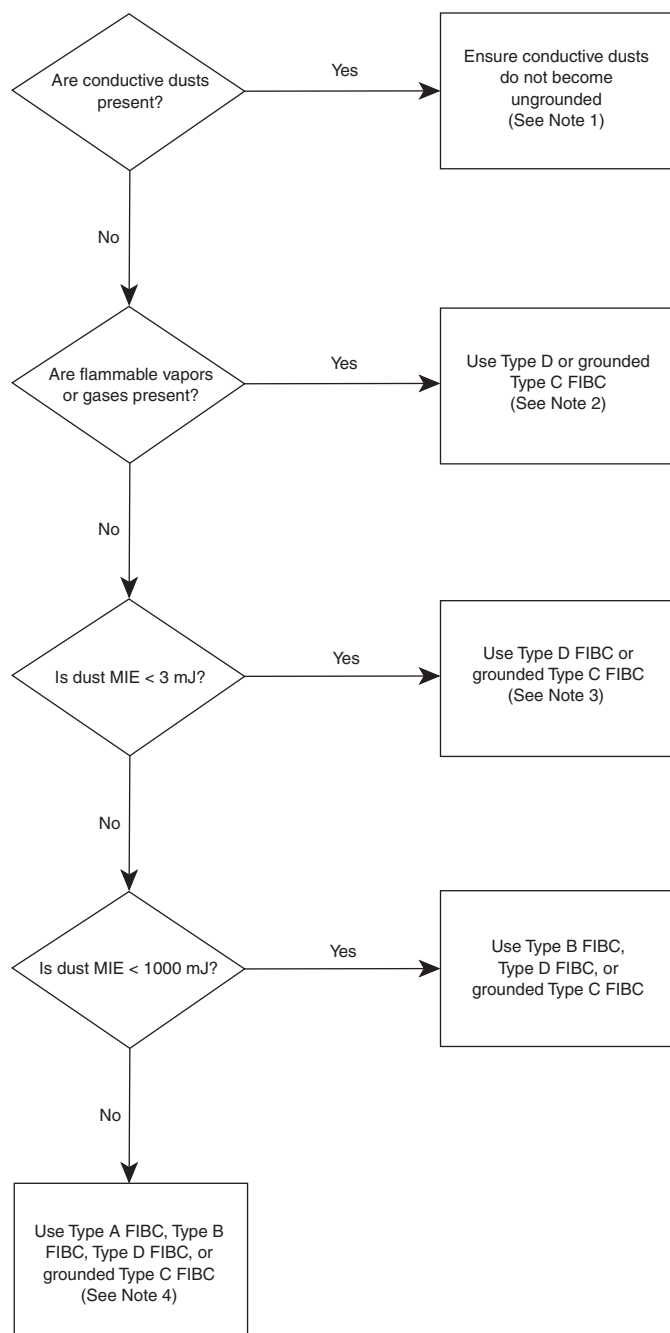
(1) Additional precautions usually are necessary when a flammable gas or vapor atmosphere is present inside the FIBC — for example, in the case of solvent wet solids.

(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.

*Measured in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, capacitive discharge circuit (no added inductance).

†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.

FIGURE A.9.6.4.6 FIBC Selection Decision Tree.

A.9.6.8.2 Diesel-powered front-end loaders suitable for use in hazardous (classified) locations have not been commercially available.

The following provisions can be used to reduce the fire hazard from diesel-powered front-end loaders used in combustible dust areas, as defined in Articles 500 and 506 of *NFPA 70*:

- (1) Only essential electrical equipment should be used, and wiring should be in metal conduit. Air-operated starting is preferred, but batteries are permitted to be used if they are mounted in enclosures rated for Type EX hazardous areas.
- (2) Where practical, a water-cooled manifold and muffler should be used.
- (3) Loaders that are certified to meet the Mine Safety and Health Administration (MSHA) criteria (formerly Schedule 31) found in 30 CFR 36, "Approved Requirements for Permissible Mobile Diesel-Powered Transportation Equipment," are also acceptable in lieu of A.9.6.8.2(1) and A.9.6.8.2(2).
- (4) The engine and hydraulic oil compartments should be protected with fixed, automatic dry-chemical extinguishing systems.
- (5) Loaders should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air could be necessary. Periodic steam cleaning also should be done.
- (6) Loaders should never be parked or left unattended in the dust explosion hazard or dust fire hazard area.

A.9.6.9.1 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.

A.9.6.10 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*; P.C. Bowes, *Self-Heating: Evaluating and Controlling the Hazards*; US Department of Energy handbook, *Primer on Spontaneous Heating and Pyrophoricity*; and V. Babrauskas, *Ignition Handbook Database*. Test methods to assess the propensity for self-heating, 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.9.6.11.2 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.9.6.11.3 Tramp metals and materials can present an ignition source for combustible materials and should be prevented from entering process streams. Both upstream and downstream equipment from the tramp material introduction point should be considered when determining the hazard zone.

A.9.6.11.4 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.9.6.12 Particular attention should be paid to the potential for a lightning strike on buildings, tanks, silos, bucket elevators, dust collectors, cyclones, and ductwork. The electromagnetic pulse from a lightning strike to these pieces of equipment can cause severe damage to any electronic equipment, including spark detection and extinguishing systems, installed on such equipment. The impulse current from a direct lightning strike can ignite combustible material within exposed equipment that can subsequently be conveyed to other locations in the facility.

A.9.6.13 Signage should be posted to designate where smoking or vaping is or is not permitted.

A.9.8.2.1 A dust explosion hazard can exist in small enclosures; however, deflagration venting or suppression measures for these units are not always possible. Consideration should be given to explosion hazards when electing to omit protection; 8 ft³ (0.2 m³) is roughly the size of a 55 gal (208.2 L) drum. Explosion prevention using inerting or pressure containment can be an effective means of managing the hazard. See also A.4.2.1.1.

While flame-resistant garments (FRG) can provide some protection for personnel from thermal exposure associated with these events, it will not provide protection against overpressure effects and projectiles.

A.9.8.2.2 See NFPA 69, Table C.2.

A.9.8.3 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, flash fire, or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources.

The requirement of 9.8.3.1 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 ft³ (1 m³) vessels. Experiments were carried out with pipe diameters of 1.1 in. (27 mm), 1.6 in. (42 mm), and 3.2 in. (82 mm), all diameters of less than 4 in. (100 mm). Corn starch ($K_{St} = 200$ bar-m/sec) and wheat flour ($K_{St} \approx 100$ bar-m/sec) were used as fuels. Even with a small pipe diameter of 1.1 in. (27 mm) and with wheat flour ($K_{St} \approx 100$ 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_{rel} 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 hazards analysis is acceptable to the AHJ.

Factors for evaluation of isolation between equipment and work areas include, among others, the anticipated P_{rel} 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_{rel}). 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 Z.1.2.24 for additional information.

A.9.9.1.2 Fire protection systems for operating enclosures are often overlooked. Subsection 9.9.1.2 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 water-reactive combustible metals, as described in Chapter 22.

A.9.9.1.2(1) Manual firefighting could pose an unacceptable risk to facility personnel and emergency responders. The evaluation of the risk to facility personnel and firefighters should be made based on discussions with the responding fire department(s) and review of the hazard assessment described in Chapter 7. Such a system(s) is needed to meet the objectives stated in Section 4.2.

A.9.9.1.2(2) The potential effectiveness of manual firefighting should be assessed by experienced firefighting personnel after reviewing the hazard assessment documentation developed in accordance with Chapter 7 requirements.

A.9.9.2.1 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 U.

A.9.9.2.4 In the case of automatic suppression systems, low momentum applications can be achieved by using small water drops or extinguishing powders and by avoiding accumulations of combustible particulate in the immediate vicinity of the discharge nozzle. In the case of dry pipe automatic sprinkler systems, it is particularly important to prevent fugitive combustible dust accumulations on or near the dry pipe because the initial discharge of compressed air can produce a suspended dust cloud and the potential for a flash fire or explosion.

In the case of manual application of extinguishing agents, 9.9.3.2 provides additional guidance on avoiding dust cloud formation during agent application.

A.9.9.3.2 Extreme care should be employed in the use of portable fire extinguishers in facilities where combustible dusts are present. The rapid flow of the extinguishing agent across or against accumulations of dust can produce a dust cloud. When a dust cloud is produced, there is always a flash fire or explosion hazard. In the case of a dust cloud produced as a result of firefighting, the ignition of the dust cloud and a resulting flash fire or explosion are quite likely. 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 flash fire or explosion hazard.

A.9.9.4.2.1 A nozzle listed or approved for use on Class C fires produces a fog discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could otherwise produce a dust flash fire or explosion potential.

A.9.9.4.2.2 Fire responders should be cautioned when using straight stream nozzles in the vicinity of combustible dust accumulations that dust clouds can be formed and can be ignited by any residual smoldering or fire.

A.9.9.5.1 A risk assessment should consider the presence of combustibles both in the equipment and in the area around the process. Considerations should include the combustibility of the building construction, the equipment, the quantity and combustibility of process materials, the combustibility of packaging materials, open containers of Class I liquids [flash point < 100°F (37.8°C)], and the presence of dusts. Automatic sprinkler protection in air-material separators, silos, and bucket elevators should be considered where water is an appropriate extinguishing agent for the hazard(s) identified.

A.9.9.5.2 Sprinkler systems in buildings or portions of buildings where water-reactive 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. In some cases, a risk assessment conducted as part of the DHA might show that the fire hazard(s) presented by other combustible materials in the space is more significant than that presented by combustible metals, a fire involving combustible metals would not result in a high enough heat release rate to activate sprinklers, and/or control of fire scenarios involving other combustibles is necessary to prevent involvement of combustible metals. In such cases, automatic sprinkler protection can be appropriate.

A.9.9.5.4 Accumulations of dust on overhead surfaces can provide pathways for the rapid spread of the fire over a large area. Subsequent opening of an excessive number of nozzles can result in a situation where the fire water supply system does not have sufficient capacity to support the design flow rate for each nozzle.

A.9.9.6.2 Clean agent and inert gas systems addressed in NFPA 12, NFPA 12A, and NFPA 2001 rely on achieving and maintaining the design concentration for at least 10 minutes to allow for suppression. For deep-seated fires such as in storage silos or bunkers, application of clean agents or inert gases above the fuel surface might not be effective. Subsurface injection of the suppressant gas might be required to extinguish smoldering within the bulk material. Therefore, clean agent systems require that ventilation in the protected enclosure must typically be shut down. This hold time can be difficult to achieve in practice in air-moving equipment such as dust collectors.

A.9.9.6.3 A release of fire extinguishing materials can suspend combustible dust creating an airborne cloud of combustible dust that the original fire can ignite, resulting in a flash fire or explosion. Care should be taken in the design of the extinguishing system to prevent creation of such a cloud and additional turbulence.

In the case of automatic suppression systems, low momentum applications can be achieved by using small water droplets 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.

Special care must be taken if using clean agent or inert gas suppression systems for combustible dust applications. These systems are generally pre-engineered for total flooding applications in buildings/rooms and are designed in accordance with NFPA 2001 to rapidly discharge agent within a short duration. The high rate of discharge and associated agent velocity is capable of suspending dust, potentially causing an explosion prior to reaching the design concentration.

A.9.9.6.5 Spark detection and extinguishing systems are usually installed to protect a down-stream asset from an upstream source of burning material. These systems rely on the air movement in the duct to carry the burning material to the extinguishing zone where a short-duration discharge of agent (often water) extinguishes the material as it travels through the zone. These systems are designed and calibrated to provide a time delay between detection and agent release that matches the transport time between the detection zone and extinguishing zone given a flow velocity within a specified range. If the flow velocity is changed after the initial system calibration, then the arrival of the burning material at the extinguishing zone will not coincide with the agent release. Also, if the air movement is shut down in response to the detection of a spark, burning material is apt to fall to the bottom of the duct before reaching the extinguishing zone and can continue burning. When the system is restarted, the burning material can be swept into the downstream asset without being extinguished. If the air movement is shut down, then provisions should be in place to extinguish burning material in the ducts before the system is restarted. See Annex R for more details on spark detection and extinguishing system design.

A.9.9.6.6 When diverters and abort gates are used, provisions should be in place to maintain air flow after the transfer of the valve or gate. Abort gates typically rely on the air flow for the motive force that makes them close. Furthermore, a fan cannot operate into a closed-off duct. When a transfer valve or abort gate operates, an alternative flow path for the air should be present. See Annex R for more details on spark detection and abort gate system design.

A.10.2.1 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 firefighting. (See OSHA's publication, *Firefighting Precautions at Facilities with Combustible Dust*, for additional information.)

A.10.2.1.2(1) Guidance for notification systems can be found in 29 CFR 1910.165, 29 CFR 1910.38, and NFPA 72.

A.21.1.3.1 Examples of facilities covered by this chapter include, but are not limited to, bakeries, grain elevators, feed mills, flour mills, milling, corn milling (dry and wet), rice milling, dry milk products, mix plants, soybean and other oilseed preparation operations, cereal processing, snack food processing, tortilla plants, chocolate processing, pet food processing, cake mix processing, sugar refining and processing, and seed plants.

A.21.4.1 Materials such as field dirt, limestone, and rock are not combustible.

A.21.4.2 The AHJ is not considered qualified to add specific requirements and changes to food safety activities, food safety programs such as sanitation programs, or grain elevator standard generated plants.

A.21.5 See Annex Y for examples of test data for selected agricultural dusts with known explosion data parameters. Other databases, such as the IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance), GESTIS-DUST-EX Database Combustion, are available for data on explosion characteristics of dusts.

Please note that the information provided in the table is for the specific agricultural dust sample tested. Explosion severity and ignition sensitivity parameters are greatly influenced by many factors, including particle size distribution, particle morphology, and moisture content. Differences in specific material composition and possible contamination will also affect explosibility parameters. Thus, the information in Annex Y will not apply in all cases.

If dealing with an agricultural dust with unknown explosion or ignition sensitivity when designing explosion protection or developing risk mitigation strategies, consider testing the dust in accordance with the relevant ASTM, ISO, or CEN standards so the data being used is as applicable as possible.

A.21.7.1.1.2 Annex H provides a checklist as an example of how one might perform a DHA for an existing facility.

Bucket elevators, belt conveyors, grinding equipment, spray dryers, and dust collectors are the pieces of equipment that have shown to be the primary sources of fires and explosions in the agricultural and food industry. Given the huge number of facilities, processes, and equipment that are in the agricultural and food industry, concentrating DHA efforts on these key pieces of equipment can help owners focus on these critical pieces of equipment with the goal of preventing those fire and explosion events. Including other equipment in the DHA proc-

ess for existing facilities will dilute the findings on the critical equipment and consume limited time and capital resources.

A.21.7.3 There are multiple methods for completing a dust hazards analysis (DHA). These include, but are not limited to, checklists, "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 Process Hazard Analysis provisions of OSHA regulations in 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals," in developing a DHA.

A.21.8.4.2.1.1 This provision states an industry- or commodity-specific threshold housekeeping dust accumulation limit within the meaning of 8.4.6.2. The housekeeping program can be a stand-alone document or included as part of another document.

A.21.8.4.2.1.2 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the horizontal and vertical surfaces of a building or equipment. This dust cloud provides fuel for the secondary deflagration, which can cause damage. The reduction of significant additional dust accumulations is, therefore, a major factor in reducing the hazard in areas where a dust hazard can exist.

A.21.8.4.2.6 These requirements supersede those in 8.4.2.6.2 because facilities under the jurisdiction of Chapter 21 do not need to comply with all of the points in 8.4.2.6.2, for instance in areas where compressed air would be used, it is not typically practical to use other cleaning methods first. The requirements in 8.4.2.6.2 would ban compressed air blowdown on overhead beams that could not be otherwise cleaned, and other common practices that need to be continued.

A.21.8.5 OSHA 29 CFR 1910.272 also establishes requirements for hot work in grain-handling operations. Hot work includes activities such as welding, cutting, grinding, brazing, powder-driving equipment, hot riveting, burning, or other flame/spark/slag-producing activities.

A.21.8.5.7.1 Ideally, all work that creates an ignition source should be done in a safe environment. When that is not possible and work has to be performed in a classified area, the performance of the work should be controlled through an ignition source control program/permit. Examples of work activities that would be associated with an ignition source control permit include concrete chipping, sand blasting, drilling into structural steel, and use of portable electric hand tools for tasks in classified areas on equipment not directly handling combustible dusts.

A.21.8.6 Facilities handling agricultural combustible dust don't typically require the use of flame-resistant garments under normal operating conditions. Where flame-resistant garments are not typically required under normal operating conditions, there might be abnormal conditions or certain tasks where flame-resistant garments are required. An assessment in accordance with Section 8.6 is needed.

A.21.8.7.1 An inspection can be accomplished by other methods besides a walk-through.

A.21.8.10 The retroactivity of Chapter 8 is not intended to require investigation of incidents that occurred prior to the adoption of this standard.

A.21.8.11 Compared to Section 8.11, this section requires the MOC elements that the technical committee considers most important to mitigate the fire, flash fire, and explosion hazards at agricultural facilities. The owner/operator can choose additional elements to include in their MOC program based on the complexity of the process or complexity of the change.

A.21.8.11.1.1 The owner/operator can determine what type of change in process materials requires management of change based on what change is important to the process and what the process is designed to handle. Examples of fire and explosion protection devices include, but are not limited to, fire sprinklers, fire doors, fire walls, detection and alarm systems, deflagration venting, explosion suppression systems, walls designed for segregation, and explosion-resistant walls.

In addition to the listed changes in 21.8.11.1.1, documented procedures should also be considered to manage proposed changes to staffing, job tasks, technology, and procedures that affect dust, fire, or explosion hazards. Establishing a documented procedure for managing changes will help identify when a qualified person is needed to assess the impact of change and to help track the outcomes of their review.

A.21.8.11.2.1 In addition to the items in 21.8.11.2.1, the following should be considered for inclusion in the documented program:

- (1) Modifications to operating and maintenance procedures
- (2) Confirmation that the change has been implemented per design prior to startup

While certain elements should be considered, they are not required for agricultural and food processing facilities.

A.21.8.11.2.1(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.21.8.11.2.1(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.21.8.12 An operational readiness review is comparable to a pre-startup safety review but includes situations other than project startups. The operational readiness review should confirm the following prior to the operation of a process:

- (1) Construction and equipment are in accordance with design specification.
- (2) Safety, operating, maintenance, and emergency procedures are in place and are adequate.
- (3) For new processes, a DHA has been performed and action items have been resolved or implemented before startup.
- (4) For modified processes, the requirements contained in 21.8.11 are met.

Users can consider more comprehensive requirements for different situations in Section 8.12.

A.21.9.3.2.1.1 For the purpose of this chapter, masonry construction refers to stone, brick, gypsum, hollow tile, concrete block, and cinder block building units, or other similar building units or materials laid up unit by unit and set in mortar.

A.21.9.3.4 The suggested minimum angle of repose of dust is 60 degrees. Vertical surfaces should be smooth to facilitate cleaning. Horizontal surfaces should be minimized to prevent accumulation of dust.

A.21.9.4.3.1 Pneumatic conveying for product transport is to be distinguished from dust collection systems that are designed to handle airborne dust. Such airborne dust systems can be used in conjunction with pneumatic conveying and are covered in 21.9.4.3.3. Other gases used in this process include carbon dioxide and nitrogen. See Annex G for installation schematics depicting typical pneumatic conveying installation concepts.

A.21.9.4.3.1.3 It is the intent of this section to apply to both new and existing systems if they meet the requirements. Ingredient transport systems that meet the specific definition are considered a lower risk activity and do not require addressing of deflagration risk. The facility should be practicing GMP, have an HACCP plan to address contamination risks, and have a sanitation plan to address dust levels and prevent the potential for ignition sources external to the system and secondary dust deflagrations. A conveying system for micro-ingredient feeders would be considered an ingredient transport system. A system to unload powdered sugar from a bulk truck would not be considered an ingredient transport system.

A.21.9.4.3.3.2 Examples of processes in starch manufacturing include starch drying, grinding, and dextrin cooking.

A.21.9.4.3.3.3 Dust control in grain or product-receiving areas consists of air aspiration or dust containment during vessel or vehicle unloading. Dust control can be achieved by baffles or enclosures with air aspiration, dust suppression, choked feeding, special belt designs, slowdown techniques, or other methods.

A.21.9.4.3.4.4 Wet or dry filtration are both acceptable methods.

A.21.9.4.4.5.1(D) 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.

A.21.9.4.4.5.2 NFPA 68 provides information on this subject.

A.21.9.4.4.6 If the return air duct air-material separator fails, a control system should be provided to direct the return air to an auxiliary filter capable of effectively entraining the dust particles, or to produce an alarm and shut down the system.

A.21.9.4.4.6.1 For bin vents, see 21.9.4.4.5.2(C). Return air ducts should have a method to prevent excessive dust from returning to the plant in the case of filter failure. Methods include, but are not limited to, use of a diverter valve that exhausts return air outside, or a series of secondary filters in the return air line designed to collect the material if part of the filter medium fails.

A.21.9.4.4.6.2 Filters used for air from negative mill pneumatics using cyclones for product separation should be permitted to be located inside of buildings without deflagration venting.

Clean air should be partially returned to the air makeup system. See the flow diagram in Figure A.21.9.4.4.6.2.

A.21.9.4.4.6.3 Filters used for hammer mills should be equipped with deflagration venting. Clean air should not be returned to the air makeup system. See the flow diagram in Figure A.21.9.4.4.6.3.

A.21.9.4.4.6.4 Filters used for product purifiers should be permitted to be located inside of buildings without deflagration venting. All clean air should be returned to the air makeup system. See the flow diagram in Figure A.21.9.4.4.6.4.

A.21.9.4.6.2 High-impact areas can include elbows and joints where changes of direction occur. The use of noncombustible ceramic or steel linings is preferred.

A.21.9.4.9.2 See NFPA 68 for information on the design of deflagration venting. Situations can occur in which it is not possible to provide calculated deflagration venting as described in NFPA 68. Such situations do not justify the exclusion of all venting. The maximum practical amount of venting should be provided, since some venting should reduce the damage poten-

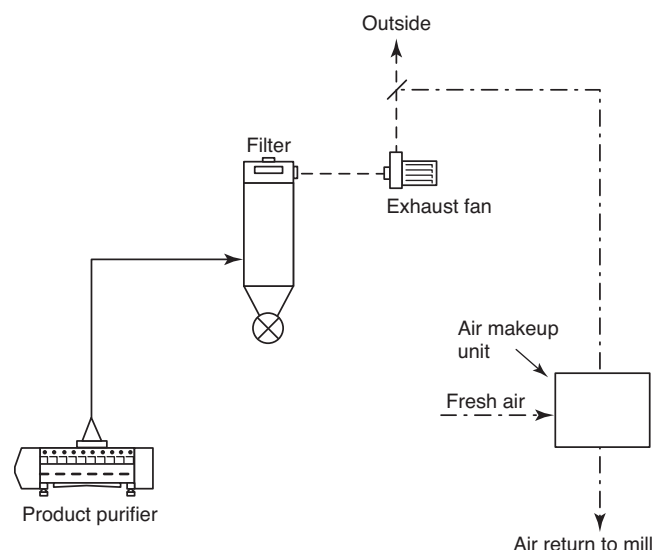


FIGURE A.21.9.4.4.6.4 Flow Diagram of Typical Product Purifier.

tial. In addition, consideration should be given to other protection and prevention methods.

A.21.9.4.9.5 NFPA 68 contains guidance on designing deflagration vents to relieve deflagrations of combustible dusts in vessels having length-to-diameter (L/D) ratios of 3 or less. Separate storage of dusts within a facility is a greater hazard due to concerns with secondary explosions. The magnitude of an explosion in a dust bin is much greater than that in a grain bin. The storage of grain dust as an ingredient in feed mill or other processes should be in separate outside bins or in bins that have external walls that are equipped with deflagration venting.

A.21.9.4.9.6.2 If a vertical vent stack cannot be installed because of structural conditions, the vent should be permitted to be located in the side of the bin, below its top, or should be permitted to be installed at an angle of up to 30 degrees from vertical.

A.21.9.4.13.1 Possible protection methods could include but not be limited to the following:

- (1) Zero speed switches
- (2) Flow indicators
- (3) Level probes
- (4) Heat sensors
- (5) Dust level sensors
- (6) Mechanical feeding devices equipped with a shear pin or overload detection device and alarm.
- (7) An alarm sounding at the operator control station.
- (8) Direct connection of drives used in conjunction with feeders, air locks, and other material feeding devices
- (9) 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

A.21.9.4.14.1.2 Access doors should be dusttight. Pits should be lighted and accessible and should provide ample room for cleaning, lubrication, repairs, and replacement of parts. Elevator boot sections and the spouts feeding them should be constructed so as to minimize choking of the boot.

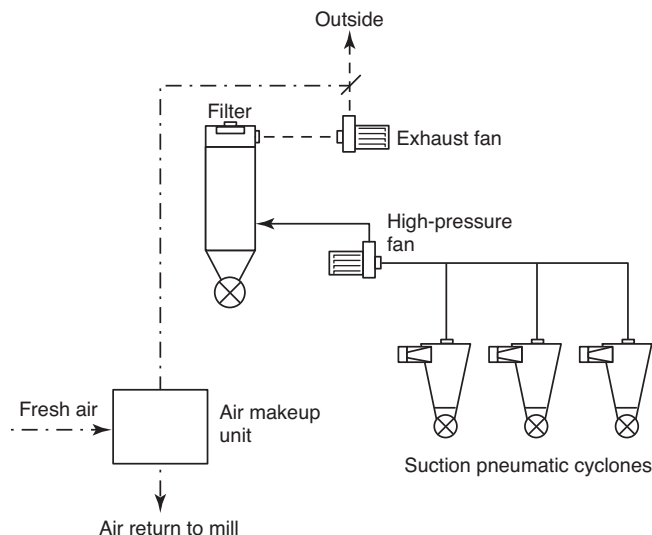


FIGURE A.21.9.4.4.6.2 Flow Diagram of Typical Pneumatic Filter Cyclone.

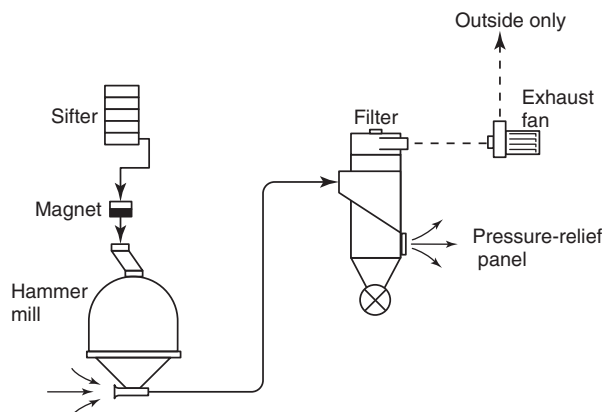


FIGURE A.21.9.4.4.6.3 Flow Diagram of Typical Hammer Mill Filter.

A.21.9.4.14.1.4 Any motor or combination of motors utilized should be no larger than the smallest standard motor(s) capable of meeting this requirement.

A.21.9.4.14.1.5 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.

A.21.9.4.14.1.12 Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether monitoring is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation. Smaller, slower bucket elevators that generate insufficient concentrations of combustible dust might not require monitoring. Prior to the 2013 edition of NFPA 61, there was an exemption from monitoring for bucket elevators operating at less than 500 ft/min (2.5 m/sec). Prior to the 2017 edition of NFPA 61, there was an exemption from monitoring for bucket elevators operating at less than 3750 ft³/hr (106 m³/hr).

A.21.9.4.14.1.12(A) This requirement is also desirable for outside legs.

A.21.9.4.14.2 Prior to the 2013 edition of NFPA 61, there was an exemption allowing bucket elevator legs handling bulk raw grain operating at less than 500 ft/min (2.5 m/sec) to be installed as inside legs. Prior to the 2017 edition of NFPA 61, there was an exemption allowing legs handling bulk raw grain operating at less than 3750 ft³/hr (106 m³/hr) to be installed as inside legs.

A.21.9.4.14.2.1 Inside legs located in concrete leg wells should be avoided. Where venting is provided for an inside bucket elevator, deflagration vents should be directed to outside areas following the guidelines of NFPA 68 and distributing leg vents along the leg as recommended. Vents should never be directed to the inside of a structure. It is preferable to locate inside legs that are to be vented next to outside walls, to minimize the length of explosion relief ducts.

Explosion suppression devices can be used in conjunction with leg feed and discharge points to limit flame propagation into structures or other grain-handling equipment.

A.21.9.4.14.2.2 Deflagration venting is recommended for all outside legs handling grain or grain products, regardless of size or use. All legs handling grain and other combustible materials, not just whole grain legs, are subject to an explosion. The leg is the most frequent location for a primary explosion to occur.

A.21.9.4.14.3.2 For guidance on deflagration venting design guidelines, see A.21.9.4.14.2.2.

A.21.9.4.14.3.3 Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether explosion protection is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation. Smaller, slower bucket elevators that generate insufficient concentrations of combustible dust might not require explosion protection. Prior to the 2013 edition of NFPA 61, there was an exemption from explosion protection for bucket elevators operating at less than 500 ft/min (2.5 m/sec). Prior to the 2017 edition of NFPA 61, there was an exemption from explosion

protection for bucket elevators operating at less than 3750 ft³/hr (106 m³/hr).

A.21.9.4.15 Throwing of grain for a considerable distance (i.e., not confined in spouts) should not be permitted unless absolutely necessary in open or semiconfined spaces, such as in barge and ship loading or in large bulk grain storage areas.

When using enclosed conveying equipment, an evaluation should be conducted to determine if ignition sources might be present and contained by the proposed enclosure. Dust collection should be considered with proper design to assure constant airflow and collection of the dust generated inside the enclosed area or device.

A.21.9.4.15.1 Examples of enclosed conveyors are enclosed belt conveyors, screw conveyors, drag conveyors, flexible screw conveyors, "sandwich" conveyors, tubular mechanical conveyor devices, etc.

The range of mitigation methods can include deflagration protection, monitoring, diversion, dust collection, dust suppression, etc.

A.21.9.4.15.2 Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature, flow, no flow indicators, motion detectors, and similar devices. Feed to the bulk material conveyors should be stopped, diverted, or otherwise handled in a safe manner.

A.21.9.4.15.5 CFR 1910.272(b)(2)(p)(2) requires that belting have a surface electrical resistance not greater than 300 megaohms. Subsection 21.9.4.15.5 requires that belting have a surface resistivity not greater than 300 megaohms per square. Surface resistance in megaohms and surface resistivity in megaohms per square are two different specifications. Surface resistance is a point-to-point measurement, and the value measured will depend on both the configuration of the electrodes and the conditions (including temperature and humidity) under which the measurement is taken. Surface resistivity is a measurement of resistance of a square unit of area and is the same regardless of the size of a material. Resistivity values can be compared across different sample geometries and test configurations, while resistance values cannot.

Some test methods, such as ISO 284, *Conveyor Belts — Electrical Conductivity — Specification and Test Method*, specify that the value reported is the resistance measured under the specified test conditions with a prescribed electrode configuration. In some cases, equipment manufacturers will include a resistance value in their product specifications instead of a resistivity value. While ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*, specifies that the resistance value be reported, it also allows the option to report resistivity values. ASTM D257 provides a calculation method to convert a resistance measurement obtained from each of the allowed test configurations to a resistivity value. An example of this conversion is provided as follows using concentric electrodes matching the dimensions specified in ISO 284:

Inner electrode diameter (D_1) = 25 mm

Outside electrode inner diameter (D_2) = 125 mm

Midpoint diameter (D_0) = $D_1 + (D_2 - D_1)/2 = 25 + (125 - 25)/2 = 75$ mm

The ASTM D257 equation for circular electrodes is as follows:

[A.21.9.4.15.5]

$$\rho_s = \frac{P}{g} R_s$$

where:

ρ_s = surface resistivity (ohm/square)

$P = \pi D_0 = 75\pi = 236$

g = gap between electrodes (mm) = $(D_2 - D_1)/2 = (125 - 25)/2 = 50$ mm

R_s = measured resistance (ohms)

Applying the values of P and g calculated from the electrode dimensions gives a conversion of $\rho_s = 4.71 R_s$

It is important to note that ASTM D257 provides multiple electrode configurations, each with its own calculation method. A reported resistance value cannot be converted to a resistivity value without knowing the configuration used to generate the value and the conditions under which the sample was tested (temperature, humidity, and sample preparation). In this case, a material satisfying the 300 megaohm/square resistivity limit would also satisfy the 300 megaohm resistance limit set by OSHA

Surface resistance and surface resistivity are not the only factors to consider. Volume resistivity should also be considered, along with the conductivity of the pulleys and the total resistance from the belt to ground.

According to NIBA — The Belting Association Technical Note 09, “Static Electricity Considerations,” extensive studies by the British National Coal Board (BNCB) (1950–1966), reported by Barelay and summarized by Norman, found that belts with a surface electrical resistance of 1×10^9 ohms or under did not retain a static charge when run on a typical grounded conveyor, while those with a surface electrical resistance of 6×10^9 ohms and greater did retain a static charge. As a result of this work, the BNCB concluded that a maximum of 3×10^8 ohms resistance was a safe condition in new conveyor belts in underground coal mines.

The International Standards Organization (ISO), the National Coal Board of Britain, and the Canadian Standards Association (CSA) have selected 300 megaohms (3×10^8 ohms) as their definition of *static conductive*. In the US, OSHA has also selected 300 megaohms (3×10^8 ohms) as the definition of *static conductive* for grain applications.

The terminology *megaohms* or *megaohms per square* is used in this standard but *megohms* or *megohms per square* is sometimes used in the industry to refer to the same unit of measurement.

A.21.9.4.15.7 For equipment lined with combustible material (other than spouts), a means should be provided to have access for firefighting. The use of noncombustible ceramic or steel linings is preferred. If combustible linings are used extensively,

it is suggested that a firebreak of noncombustible lining material be used at a grain stream direction change point.

A.21.9.4.15.9 Spout openings in distributors and turnheads should be closed when not in use, to reduce the likelihood of propagation of flame through idle spouts.

A.21.9.4.16.2 Typical methods include magnets, screens, or other methods of detection or classification and that could occur in upstream processes.

A.21.9.4.16.5 The following information from FM Property Loss Prevention Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire*, Chapter 2.3.4.6, and CCPS *Guidelines for Safe Handling of Powders and Bulk Solids*, Chapter 5.3.2, Blenders and Mixers, will be helpful when conducting a DHA.

When filling and emptying a mixer, mixer components must run only with tip velocities of ≤ 1 m/sec, safeguarded by technical measures (e.g., motor speed controller and shutdown system).

During operation in a closed condition, the rotational speed of the mixer parts (internal rotating elements) is not limited if the blades are completely covered by the material or if the filling level is 70 vol. % or more.

Circumferential velocities (tip speeds) of up to 10 m/sec can be tolerated during filling a mixer that is filled below 70 vol. % if the autoignition temperature (AIT) of the solids to be mixed is above the limits given in Table A.21.9.4.16.5.

Also refer to A.9.6.11.4 for blender tip speed criterion.

A.21.9.4.17.2 Static deposits of combustible dust on heated surfaces are subject to ignition due to carbonization of the dust. Understanding of the mechanism involved is lacking, but it does appear that there is no direct relationship between the temperature necessary to ignite a dust cloud and that necessary to ignite a dust layer. Rather, a time-versus-energy (temperature) relationship appears to be involved. The higher the temperature, the shorter the time needed for carbonization and subsequent ignition.

The energy necessary to ignite a dust cloud has to be great enough to raise the dust particles to their ignition temperature and overcome heat losses to the surrounding air. The energy has to be of sufficient duration to ignite enough adjacent dust particles to sustain propagation of the flame front. A static dust deposit has none of the dynamic motion and heat losses of a dust cloud. Also, the insulating characteristics of organic dusts act to retard the heat loss from particles of dust in intimate contact with the heated surface. Thus, a lower temperature is necessary to establish the time–energy relationship leading to ignition. This behavior, combined with the fact that the ignition temperature of an organic dust is lowered by prolonged heat exposure, gives cause for concern over dust deposits on heated surfaces. The ignition of a dust layer and the subsequent quiescent burning can provide the pilot flame necessary to ignite a dust cloud.

A.21.9.4.17.2.2 For information on other dryers, see NFPA 86.

Table A.21.9.4.16.5 Autoignition Temperature (AIT) Limits

MIE, mJ	1–3	3–10	10–30	30–100	100–300	300–1000	>1000
AIT Deg. C	530	500	465	430	395	360	325

A.21.9.4.17.2.3 Spontaneous ignition is a primary cause of dryer fires and explosions. The requisites of this phenomenon are a heated surface or a hot airstream, a layer of product exposed to this heat, and time.

A.21.9.4.17.3 Typically, a grain dryer is a self-contained unit that processes bulk quantities of an agricultural commodity either by continuous flow or in batch quantities. The dryer is usually located on the plant property, adjacent to the elevator, storage building, or tank. The commodity, either directly from harvest or from interim storage, contains extraneous materials, partly as a result of harvesting, that have a tendency to interfere with the drying process and to contribute to fires within the dryer itself.

A.21.9.4.17.3.1 Particular attention is needed when adjacent buildings or structures are of combustible construction or have walls with vents, windows, or spout or conveyor openings.

A.21.9.4.17.3.3(A) The dryer can be direct fuel-fired (i.e., the products of combustion enter the drying chamber) or indirect fuel-fired (i.e., the products of combustion do not enter the drying chamber).

A.21.9.4.17.3.3(B) Typically, the firing rates of grain dryers are on a demand basis created by a temperature-measuring device located in the heated airstream prior to its contact with grain. The demand set point is chosen to produce the desired degree of dryness or moisture removal.

This control arrangement maintains the air temperature within the upper and lower temperature ranges of the measuring device. If the temperature range is exceeded, the burner firing rate is reduced, and when the temperature drops below the lower range, the burner firing rate is increased.

This control arrangement is satisfactory for most operating conditions, grain moisture content, and ambient temperature conditions. Operators usually recognize that they need to increase the dryer temperature setting if the grain is unusually wet and possibly slow down the rate of grain flow through the dryer. It has to be recognized that the burner needs to operate at abnormally high firing rates when the outside temperatures are unusually cold.

A.21.9.4.17.3.6(E) One or a combination of the following methods, depending on local conditions, should be used:

- (1) Fixed water spray or automatic sprinkler systems with adequate water supplies (*see NFPA 13 and NFPA 15*)
- (2) Hose lines, 1½ in. (38 mm), of sufficient length to reach all access openings on the dryer, connected to a 2 in. (51 mm) or larger water supply line (*see NFPA 14*)
- (3) Small-diameter hose lines of sufficient length to reach all access openings on the dryer and supplied by the domestic water system
- (4) Fixed water spray or automatic sprinkler systems supplied by a dry standpipe
- (5) An adequately designed steam-smothering system
- (6) Class A portable fire extinguishers

A.21.9.4.17.5.2(A) Spontaneous ignition is a primary cause of dryer fires and explosions. The requisites of this phenomenon are a heated surface or a hot airstream, a layer of product exposed to this heat, and time. In the case of starch, a catalyst appears to be water from leaks or condensation. Fires have occurred in such accumulations at normal operating temperatures of 177°C (350°F). Thus, the control of these elements

through design, operation, cleaning, and maintenance will prevent explosions from this ignition source.

A.21.9.4.17.5.2(B) Typical points where spontaneous ignition is likely to occur include the following:

- (1) Adjacent to steam coils that are subject to starch accumulation
- (2) In tubes or ducts of dryers where starch can accumulate (e.g., in elbows below a vertical run where entrained dust will fall when the fan is shut off, where there is a sharp change of direction from vertical to horizontal, and where there is a marked change to a lower velocity, such as a duct leading into a cyclone)
- (3) Near burners to detect carbon buildup

A.21.9.4.17.5.4(A) Where an outside dryer is provided with adequate deflagration venting, fire protection or explosion suppression systems are not always necessary.

A.21.9.4.17.6.4(C) See A.21.9.4.17.3.6(E).

A.21.9.4.19.1 Additional information and guidance for heat transfer systems can be found in NFPA 30 and NFPA 87.

A.21.9.4.19.1.2(C) Communication between hazardous and heat-producing areas should be arranged so that a fire partition, fire wall, and so forth, with all openings closed, is always between the hazard and the heat-producing area. The fire-break could be a nonhazardous room, entryway, airlock, and so forth, arranged so that the communicating opening between the room and the hazardous area will not be open when the communicating opening between the room and heat-producing area is open, and vice versa.

A communicating opening such as machinery doors is permitted, provided that these doors are kept locked and are only opened when either the hazardous area or the heat-producing area is shut down and will not cause a fire or explosion with the machinery door open.

A.21.9.4.19.1.4 See A.21.9.4.17.2.

A.21.9.4.21.1 Openings of 2½ in. × 2½ in. (64 mm × 64 mm) should be used on grating for receiving pits, to limit entry of foreign objects. Larger openings could be needed to accommodate some materials, such as whole corn cobs and hay cubes.

A.21.9.4.21.1.2 Such devices should be installed on hoppers, conveyors, or spouts that handle grain from truck dump pits, railcar dump pits, and barge or ship unloading systems prior to entry of the grain into subsequent conveyors, elevators, or processing machinery, to minimize the entry of tramp metal and other foreign objects.

A.21.9.4.21.1.3 NFPA 77 provides information on this subject.

A.21.9.5.1 Dust collection systems are designed to handle airborne dust as distinguished from pneumatic conveying for product transport.

Techniques to prevent or reduce dust generation and dispersal are vital to any dust control program. These techniques include the use of reduced handling speeds, dead boxes, choked feeding, snorkel loaders, dusttight enclosures, short vertical runs, cleaning, and dust suppressant, as well as many others. Preventive dust control is encouraged, since it can effectively reduce total dust control costs as well as the demands placed on the performance of subsequent dust control techniques outlined in Section 8.4, 21.8.4, Section 9.5, and 21.9.5.1.

Various oils and other liquids have been used as a dust suppressant. Each dust suppressant has its limitations and should be used with regard to applicable grain and food standards and regulations. Oil dust suppressants should not be applied directly into the leg, as there have been cases of belt slippage using oil. Application should be made in the transition spout between the receiving pit and the receiving leg. If this is not feasible, application can be made at a transfer point or discharge of a conveying system, or directly on a conveyor belt or into a screw auger. The idea is to apply the dust suppressant where there is grain turbulence, thereby allowing the dust suppressant to mix thoroughly.

A.21.9.5.1.1 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.

A.21.9.5.1.5 Legs are the most frequent location of known primary dust explosions and can experience malfunctions, which can result in ignition of the returned dust. This section is not intended to apply to point-of-use dust collectors.

A.21.9.5.1.7 The purpose of this dust control method is to remove displaced air from the equipment so that it operates under a slightly negative pressure in order to reduce fugitive dust emissions from the equipment, keep the dust generated from the material being conveyed with the material, and eliminate the propagation hazard of interconnecting the conveying equipment with a central dust collection system. The dust is not removed from the equipment, and this approach does not lower the risk of a dust deflagration within the equipment itself. The point-of-use dust collector should be located near the material inlet point on the conveyor. Little dust should be drawn into the point-of-use collector.

When used on a bucket elevator leg, it is recommended that the point-of-use dust collector be installed in the down leg of the bucket elevator leg to facilitate dust release from the filters. The cross-sectional area of the transition between the duct and the leg casing should be 2.5 times the cross-sectional area of the dust collector inlet. The angle of the transition duct to the leg casing should be no less than 60 degrees.

This dust control method should be used in conjunction with a good housekeeping program, equipment maintenance strategy, and dust deflagration mitigation actions as required.

A.21.9.5.1.7(7) Filtering efficiency specifications are provided by manufacturers. There are commercially available dust collectors using filters, both bag and cartridge type, that can be warranted by the supplier to meet this specification for a specific application. The filtering efficiency can also be verified by testing of existing equipment.

A.21.9.6.4.4 Pillow block bearings are preferred for head, tail, and bend pulleys.

A.21.9.6.6 NFPA 77 provides information on this subject. For information about using flexible intermediate bulk containers, see 9.6.6.4.

Small static charges generated by clothing are typically not sufficient to ignite agricultural combustible dust.

A.21.9.6.6.1.4(B) As an example, grounding both ends of a piping system consisting of a positive displacement blower, a number of piping sections, and a cyclone receiver means the blower and the cyclone would be grounded.

A.21.9.6.6.1.4(C) See "6-3.2.2 Flexible Boots and Socks" by Laurence G. Britton in *Avoiding Static Ignition Hazards in Chemical Operations*. Examples of knitted fabric include cotton, polyester, and cotton/polyester blends as used for flexible connectors for rotary and vibratory sifters and cleaners.

A.21.9.6.6.2 Where the combustible dust material has a low minimum ignition energy (MIE), typically below 20 mJ, it is possible that high rates of material discharge into or out of vessels or containers such as FIBCs can result in ignition in some circumstances. See additional annex material in A.9.6.6.2.

A.21.9.6.14.2 NFPA 499 contains guidelines for determining whether an area should be categorized as a Class II area.

A.21.9.6.15.2.1 Internal combustion engine-powered heavy equipment (such as front-end loaders, skid steers, cranes, backhoes) suitable for use in hazardous locations has not been commercially available. The following provisions can be used to reduce the fire hazard from heavy equipment used in combustible dust areas, as defined in Articles 500 and 506 of *NFPA 70*.

- (1) Only essential electrical equipment should be used, and wiring should be in metal conduit. Air-operated starting is preferred, but batteries are permitted to be used if they are mounted in enclosures rated for Type EX hazardous areas.
- (2) Where practical, a water-cooled manifold and muffler should be used.
- (3) Heavy equipment that is certified to meet the Mine Safety and Health Administration (MSHA) criteria (formerly Schedule 31) found in 30 CFR 36, "Approved Requirements for Permissible Mobile Diesel-Powered Transportation Equipment," are also acceptable in lieu of A.21.9.6.15.2.1(1) and A.21.9.6.15.2.1(2).
- (4) The engine and hydraulic oil compartments should be protected with fixed, automatic dry-chemical extinguishing systems.
- (5) Heavy equipment should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air could be necessary. Periodic steam cleaning also should be done.
- (6) Heavy equipment should never be parked or left unattended in the dust explosion hazard or dust fire hazard area.

A.21.9.6.15.4 Exterior docks should open at least on one side, and exterior platform areas should be considered to meet the "outdoor" provision.

A.21.9.6.15.5 Cleaning should be done at 4-hour intervals during periods of steady operation and at the end of each workday.

A.21.9.8.1 To better understand the hazards of the operations and how to apply the provisions of this standard to a facility and operations, a hazards analysis can be conducted regarding the deflagration properties of the materials being handled, the equipment used, and the operations. See Table Y.2(a) or use equivalent test data for deflagration properties of agricultural or food dusts.

It should be noted that the protections described in Section 9.8 and 21.9.8 might not, in themselves, eliminate explosion or deflagration propagation. Other means, when practicable, such as rotary valves, fast-closing valves, conveyor seals, or chokes can minimize propagation potential. Ultimately, if adequate deflagration venting is provided or equipment fails, explosion propagation could still be possible. Additional information on deflagration isolation can be found in NFPA 69 and Annex T.

A.21.9.8.1.1 See NFPA 68 for information on the design of deflagration venting.

A.21.9.8.1.1.1 These are locations in which combustible dust is in the air in quantities sufficient to produce explosive or ignitable mixtures under normal operating conditions, or locations where mechanical failure or abnormal operation of machinery or equipment could cause explosive or ignitable mixtures to be produced, and could also provide a source of ignition through simultaneous failure of electrical equipment, operation of protection devices, or other causes.

Situations can occur in which it is not possible to provide calculated deflagration venting as described in NFPA 68. Such situations do not justify the exclusion of all venting. The maximum practical amount of venting should be provided, since some venting should reduce the damage potential. In addition, consideration should be given to other protection and prevention methods.

A.21.9.8.1.1.1(C) If an deflagration vent recloses after relieving an explosion pressure wave, an implosion can occur.

A.21.9.8.2 See A.21.9.8.1.

A.21.9.8.2.2 When explosion protection methods (such as venting, suppression, etc.) in bins, silos, or tunnels cannot be fully utilized, all required prevention methods in this standard should be utilized (such as bearing sensors, belt alignment sensors, speed monitors, housekeeping, management systems, dust control systems, etc.).

Protection methods that could also be considered include, but are not limited to, separating the bin or silo from other structures and from areas where personnel are located; avoiding intervening the bins and silos; incorporating a weak seam roof into the bin or silo design; and arranging fill equipment in a manner such that the fill spouts are closed on bins and silos not being filled. An additional consideration could be calculating the surface area needed to do partial volume venting of a bin or silo to provide protection from a less-than-worst-case deflagration. For example, if a bin or silo is normally 75 percent full before the headspace is above the MEC, the venting calculation should be based on 25 percent of the silo volume.

A.21.9.8.2.3 See NFPA 68 for information on determining the appropriate deflagration venting area and arrangement. For information on venting bucket elevators, see the National Grain and Feed Association Research report, *Emergency Preplanning and Fire Fighting Manual — A Guide for Grain Elevator Operators and Fire Department Officials*.

A.21.9.8.3.1 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Chokes, flame front diverters, and abort gates are not acceptable devices for explosion isolation due to lack of specific test standards to validate

the design. However, these devices can still provide benefits such as reducing pressure transmitted to connected equipment. Determining the need for isolation is normally part of the DHA.

A.21.9.8.3.2 Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations, where the discharge of a fireball from the pickup point endangers personnel.

A.21.9.8.3.2.1 A common example for the application of such isolation would be in the upstream ductwork associated with a dust collection system servicing a work area. Loading chutes less than 10 ft (3 m) in length and designed for gravity flow are not considered as ductwork. Determining the need for isolation is normally part of the DHA.

A.21.9.9 See Annex D for supplementary information on fire protection.

A.21.9.9.4.1.2 An operating area is an area where personnel can be present to perform operational or maintenance tasks.

A.21.9.9.4.1.3 Examples of combustible contents are finished products and raw material in paper or cloth bags, cardboard boxes or containers, wood pallet storage, and packing material storage.

A.21.10.3 Personnel safety precautions to be familiar with ahead of responding to process equipment smolders or fires include explosible off gasses generated when introducing water, equipment failure/collapse, and risk to personnel increases on top of equipment.

Close cooperation between local fire officials, emergency agencies, and facility management are an essential ingredient for a successful fire and emergency action plan. Fires and emergencies in grain handling facilities are unique compared to those that occur in other structures and might require special equipment and techniques. A coordinated effort between facility management and fire and emergency response agencies is necessary to ensure the most effective and safest means to deal with fires, explosions, and other emergencies are developed and used. Some steps that fire department personnel can take to prepare are the following:

- (1) Visit the facility.
- (2) Develop written emergency plans.
- (3) Train firefighters and facility employees in techniques for approaching and controlling grain-related fires.
- (4) Establish mutual aid plans with other fire departments, including arranging for the availability of special equipment.

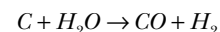
Identification of a smolder or fire within process equipment is commonly observed by thermocouple internal to bin, discoloration of process material, discoloration of metal equipment housing, presence of smoke, and CO generation. Assessment of the state and location of the fire or smolder can be achieved through visual observation, off gas detection, thermocouple, and thermography.

Further smolder and fire prevention, identification, assessment and firefighting resources available include NFPA 69, Annex B; *Silo Fires: Fire extinguishing and preventive and preparatory measures*, published by the Swedish Civil Contingencies Agency; and NGFA *Emergency Preplanning and Fire Fighting Manual — A Guide for Grain Elevator Operators and Fire Department Officials*.

The following are incipient firefighting techniques for agricultural dust fires:

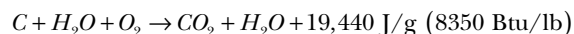
- (1) *Leg Fires.* Material flow into a leg should be stopped and the leg should be shut down. Leg fires should be extinguished by water fog or gentle application of water. Fires should be located by feeling the leg casing for heat or observing discoloration of metal. If the location is unknown, water should be applied first in the boot section, then in the bin-pulley access door, and last in the head section.
- (2) *Conveyor Belt Fires.* The conveyor belt should be shutdown (halted). Conveyor belt fires should be extinguished by application of water. Material flow to the conveyor belt should be stopped. If necessary, the belt should be cut to isolate the fire.
- (3) *Dryer Fires.* Dryer fires should be extinguished by removing burning material from the dryer or gentle application of water. Fuel to burners, fans, and material flow into the dryer and from the facility should be stopped. If necessary, emergency dump should be used to remove material from the dryer.
- (4) *Concrete Bin or Silo and Steel Tank Smolders and Fires.* The risks and responses to a smolder and fire within bins, tanks and silo differ. Supplying firefighting water to grain storage, although sometimes necessary, introduces additional risk due to the explosible off gasses generated. Removing the material from the process and fighting the smolder or fire externally is typically the preferred method. When removing non-free-flowing material from the bin or silo, attempt removal first by mechanical means (vibrator, bin sweep, scraper, probing/poking with poles, etc). Be aware that a normally free-flowing product could become non-free-flowing due to caking, heating, moisture, and so forth. If the stored product is non-free-flowing and cannot be removed by mechanical means, then the smolder or fire must be extinguished while the product is inside the bin to prevent structural compromise to the bin or silo.
 - (a) *Concrete Bin or Silo and Steel Tank Smolders.* A deep-seated smolder in a bin, tank, or silo should not be extinguished with water. The addition of water can generate CO that would build up in the bin and potentially explode [see list item (6)]. A better approach is to inject inert gas (such as carbon dioxide or nitrogen) to displace the oxygen and smother the smolder. It is important to note that nitrogen gas is preferred over carbon dioxide for inert gas injection based on explosions that have occurred due to carbon dioxide injection leading to electrostatic ignition of explosive concentration of off gasses in headspace. For smaller and more remote facilities, their ability to employ the use of inert gas injection might be limited due to the availability of nitrogen gas in bulk and the burdensome requirements related to on-site generation and storage. Other “best available techniques” for smolder detection and extinguishment include the following:
 - i. CO/multigas detection
 - ii. Drones equipped with thermographic imaging cameras
 - iii. Pre-engineered and pre-installed nozzles for inert gas injection and associated piping
 - iv. Delivery/availability of the inert gas addressed during the design/planning phase
 - (b) *Concrete Bin or Silo and Steel Tank Fires.* Concrete bin or silo fires should be extinguished by wetting the top surface of the material with gentle application of water at a low flow rate directly to the burning materials, and then removal of burning material from the bin or silo directly to the outside. Fire should be located by thermometer probes, thermographic photography, or feeling heat on bin or silo surfaces. Openings to the bin or silo should be sealed to limit oxygen entry. Material flow to and from the bin or silo should be stopped. Firefighting operations should be done from outside the bin or silo. Fires should be isolated by selective unloading of material onto the ground.
- (5) *Fumigant or Chemical Fires.* Fires involving fumigants containing phosphine should be extinguished by inert material or nonaqueous agent used for Class B fires. Water should not be used for phosphine fires to avoid exothermic reaction and development of explosive gases.
- (6) *Water Gas Reaction.* Application of small amounts of water on glowing grain in a partially confined space, such as a grain silo, and in the presence of air can generate a water gas reaction. The glowing grain must be at a temperature of at least 1290°F to 1470°F (700°C to 800°C), and initial water contact might not cool the mass of glowing grain below 1110°F (600°C). The partial oxidation reduction between carbon and water forms carbon monoxide and hydrogen as shown in Equation A.21.10.3a.

[A.21.10.3a]



In the presence of oxygen (air), the carbon monoxide and hydrogen burn, immediately releasing heat as shown in Equation A.11.10.3b.

[A.21.10.3b]



In a partially confined space, the combustion energy will rapidly pressurize the space beyond what the silo walls or tops can withstand, causing destruction of the silo.

A.22.1.1 Under proper conditions, most metals in the elemental form will react with oxygen to form an oxide. These reactions are exothermic. The conditions of the exposure are affected by the temperature of the metal (whether it is in large pieces or in the form of small particles), the ratio of its surface area to its total weight, the extent or presence of an oxide coating, the temperature of the surrounding atmosphere, the oxygen content of the atmosphere, the moisture content of the atmosphere, and the presence of flammable vapors.

A.22.1.1.1 Any metal in a fine enough form can be combustible and/or explosible.

A.22.1.1.2.2 Ignitable metal fibers/flyings would be anticipated to be identified as a combustible metal in accordance with Section 22.5.

A.22.1.1.2.3 Operations such as welding, laser cutting, and plasma cutting should be considered to be within the scope of

this chapter unless the fumes collected from these processes can be shown to meet the requirements for exclusion in 22.5.2.4.

A.22.1.1.3 Products or materials that have the characteristics of a combustible metal should have a safety data sheet (SDS) that describes those burning characteristics. The manufacturer or technical personnel with knowledge of the hazards associated with the metal should be consulted to characterize the hazards of the metal. [See Table A.22.1.1.3 and Annex Y.]

Table A.22.1.1.3 Metal Properties — Key Temperatures

Metal	Melting Point (°C)	Boiling Point (°C)	Solid Metal Ignition (°C)	Max. Adiabatic Flame Temperature* (°C)
Aluminum	660	2452	555	3790
Barium	725	1140	175	—
Boron	2300	2550		3030
Calcium	824	1440	704	—
Chromium	1857	2672		2900
Copper	1085	2567		1250
Hafnium	2223	5399		4580
Iron	1535	3000	930	2220
Lithium	186	1336	180	—
Magnesium	650	1110	623	3340
Manganese	1246	1962		—
Molybdenum	2617	4612		2390
Nickel	1453	2732		2130
Niobium	2468	4927		3270
Plutonium	640	3315	600	—
Potassium	62	760	69	—
Silicon	1410	2355		2970
Sodium	98	880	115	—
Strontium	774	1150	720	1980
Tantalum	2996	5425	—	3490
Thorium	1845	4500	500	—
Titanium	1727	3260	1593	3720
Tungsten	3422	5660		2830
Uranium	1132	3815	3815	—
Zinc	419	907	900	1800
Zirconium	1830	3577	1400	4690 [†]

*Maximum adiabatic flame temperature calculations from Cashdollar and Zlochower, *Journal of Loss Prevention in the Process Industries*, vol. 20, 2007.

[†]Adiabatic flame temperature for zirconium from National Energy Technology Laboratory (NETL), Albany, OR.

A.22.1.1.6 The number of mixtures containing metals is infinite. Mixtures could contain one or more of the following materials in any range of concentration: metals, metal oxides, inorganic compounds, organic compounds, oxidizers, ignitable (flammable or combustible liquids), water, and water-based solutions. Consequently, the mixture could exhibit a range of hazards from none to more than one physical hazard based on content, composition, form, and moisture content. In some cases, a mixture can be more hazardous than the individual metal(s) — for example, pyrotechnics. A representative sample of a mixture containing one or more metals requires characterization and testing. Characterization includes a breakdown of the constituents, form(s), particle size and distribution where applicable, moisture content where applicable, and propensity to separate. If the composition or particle size of the mixture changes, a new representative sample should be collected and evaluated.

A.22.1.1.6.2 Metal-containing mixtures where the primary hazard is from combustible metals and the mixture behaves as a metal are covered by Chapter 22. Mixtures where the primary hazard is from nonmetals and the mixture behaves as a nonmetal might be covered by other industry- or commodity-specific standards. The criteria in 22.1.1.6.2(1), 22.1.1.6.2(2), and 22.1.1.6.2(3) determine whether the mixture can be extinguished using conventional firefighting measures commonly prescribed in other standards. See 22.9.9.3.1.1 for additional information on the criteria in 22.1.1.6.2(1) and 22.1.1.6.2(2). List item 22.1.1.6.2(4) examines the volume resistivity of the mixture. NFPA 77 defines conductive solids as having a resistivity less than 10^5 ohm-m. This requirement provides a factor of ten increase reflective of some quantity of lower resistivity material in the mixture. Metal mixtures present additional ignition hazards associated with conductivity, such as arcing at electrical contacts and a propensity for static discharges. List item 22.1.1.6.2(5) addresses thermite reactions, which are not covered by other standards.

Additional analysis such as differential scanning calorimetry (DSC) and thermal gravimetric analysis (TGA) in air might be warranted to determine if the primary hazards of a mixture are due to combustion of metals or combustion of nonmetals in the mixture.

Since there is often a wide variety of mixture compositions in a facility, mixture composition variations should be documented, and the selection of the particular mixture sample submitted for testing should be described with the basis of selection included. If the mixture is combustible and is to be excluded from this chapter, either Chapter 25 or some other combustible dust chapter or standard should be used to establish suitable fire and explosion protection measures. For additional guidance on water reactivity tests, see Janés, A., *Journal of Loss Prevention in the Process Industries*.

Metals that can undergo exothermic oxidation-reduction (thermite) reactions include aluminum, magnesium, titanium, zinc, silicon, and boron. Metal oxides that can react with these metals include iron oxide, manganese oxide, copper oxide, lead oxide, and silicon oxide. Iron oxide (rust) is the most common oxide in thermite reactions.

A.22.1.1.7 Regulations for the domestic shipment of dangerous goods (lithium and lithium alloy materials are so classified) are issued by the Department of Transportation (DOT), 49 CFR 100–199, which has specific responsibility for promul-

gating the regulations. These regulations are updated and published yearly by DOT.

International shipments are regulated by the United Nations, International Air Transport Association, International Maritime Organization, and other national agencies.

A.22.1.1.11 A combustible metal is a metal that meets the criteria for combustibility as defined in Section 22.5. The quantities listed in Table 22.1.1.9.1 are for the entire occupancy, not for individual fire control areas. This table is not intended to provide the MAQ. This chapter does not address MAQs for construction types; however, based on the specific hazards of the combustible metal, the MAQ from the governing building codes might apply.

The presence of combustible metals in quantities below the thresholds provided in Table 22.1.1.9.1 can still pose hazards, but those hazards might not warrant the full extent of Chapter 22 requirements.

Instead, limited fire and explosion preventative and protection measures for the application should be implemented. Such measures might include the following:

- (1) An educational laboratory use of less than 0.23 kg of some combustible metals might warrant the use of flame-resistant garments and other precautions.
- (2) Open or partially open containers, powder transfer operations, and potential emergency situations should be reviewed with regard to Chapter 22 and metal storage, transfer, and emergency response requirements, even when the threshold has not been met.

A.22.5.2 Combustible metals and dusts and alloys of those metals provide varying degrees of hazard for fire and explosion risk. Hazard assessment for process and facilities is difficult without quantitative test data for the specific materials and their forms. The foundation for the primary basis of safety, as well as the extent to which other NFPA standards require compliance, is a function of the actual properties of the materials under consideration. Reliance on historical, dated, or similar available test data is highly discouraged. Specific properties of the specific forms of combustible metals and dusts will dictate test results and the corresponding level of risk. No generalizations or substitutions of a similar kind are acceptable or prudent to use.

The requirements contained in this document provide the minimum requirements necessary to facilitate safe manufacturing, handling, and processing of these materials. Combustible metals can be made in specific forms that require additional safeguards to provide safe handling. The specific nature of additional safeguards should be determined by using the results of a hazard assessment.

A.22.5.2.5 Some materials are subject to change, such as oxidation 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. Examples of variations in process and material conditions include changes in the abrasive materials in sanding and polishing operations, cutting blade wear and cutting oil contamination causing changes in cuttings and dust particle size distribution and composition, and ambient temperature and humidity variations affecting the extent of metal oxidation. Metal recycling facilities experience large variations in particulate and contaminant compositions of received materials. These varia-

tions should be assessed to determine when and where to obtain sample materials that represent the most combustible compositions and the smallest particle sizes. If combustibility and particle size variations cannot be assessed without testing, multiple samples should be collected and submitted for testing.

A.22.5.2.7 The physical hazards of metals and metal-containing metals in combustible form depend on material properties. Changes in the form or composition of the material can result in a change in the type and degree of hazard. The results of combustibility and explosibility screening tests are meaningful when the sample subject to testing is well characterized and reported with the results. The age of a sample can influence test results; therefore, fresh samples are likely more representative and preferred for determination of combustibility.

A.22.5.2.7.1 Examples of identifiers include the process equipment collected from, the lot number, etc. A photographic record of the sample location can be used to further document and identify samples, and the photo should include a date stamp. If the sample is collected from a drum, the drum label can be photographed. If the sample is collected from on top of or inside process equipment, an overview photograph and photographs before and after sampling can be used to identify different process equipment and heights. Samples should be collected from rooms and sources known to pose or amplify combustible dust fires and explosions.

Special consideration should be given to metal containing samples from equipment such as dust collectors, impact equipment, bins, processing equipment, ovens, furnaces, dryers, conveyors, bucket elevators, etc. If it is taken from a dust collection or pneumatic conveying system, the sample should represent the hazard subject to evaluation.

Samples should be collected from rooms and buildings where metals might exist in combustible form, including rooms where abrasive blasting, cutting, grinding, polishing, mixing, conveying, sifting, screening, bulk handling or storage, packaging, agglomeration, and coating are performed.

A.22.5.2.7.2 See Figure A.22.5.2.7.2 for typical basic material characterization. The particle size distribution should be characterized by the DV50 and DV10 values.

A.22.5.2.8.1 Tests of representative samples are preferred. Historical data can be used but require an assessment of data to determine if they are truly representative of the material being analyzed.

A.22.5.2.8.2 Examples of properties that should be assessed are as follows:

- (1) Composition
 - (a) Pure materials
 - (b) Mixtures (including diluents or grinding media)
 - (c) Treatment such as oxidation
 - (d) Aging
- (2) Form
 - (a) Particle size
 - (b) Morphology (angular, acicular, spherical, fiber, irregular, agglomerate)
- (3) Distribution
 - (a) Friability of solids and particle attrition through the process

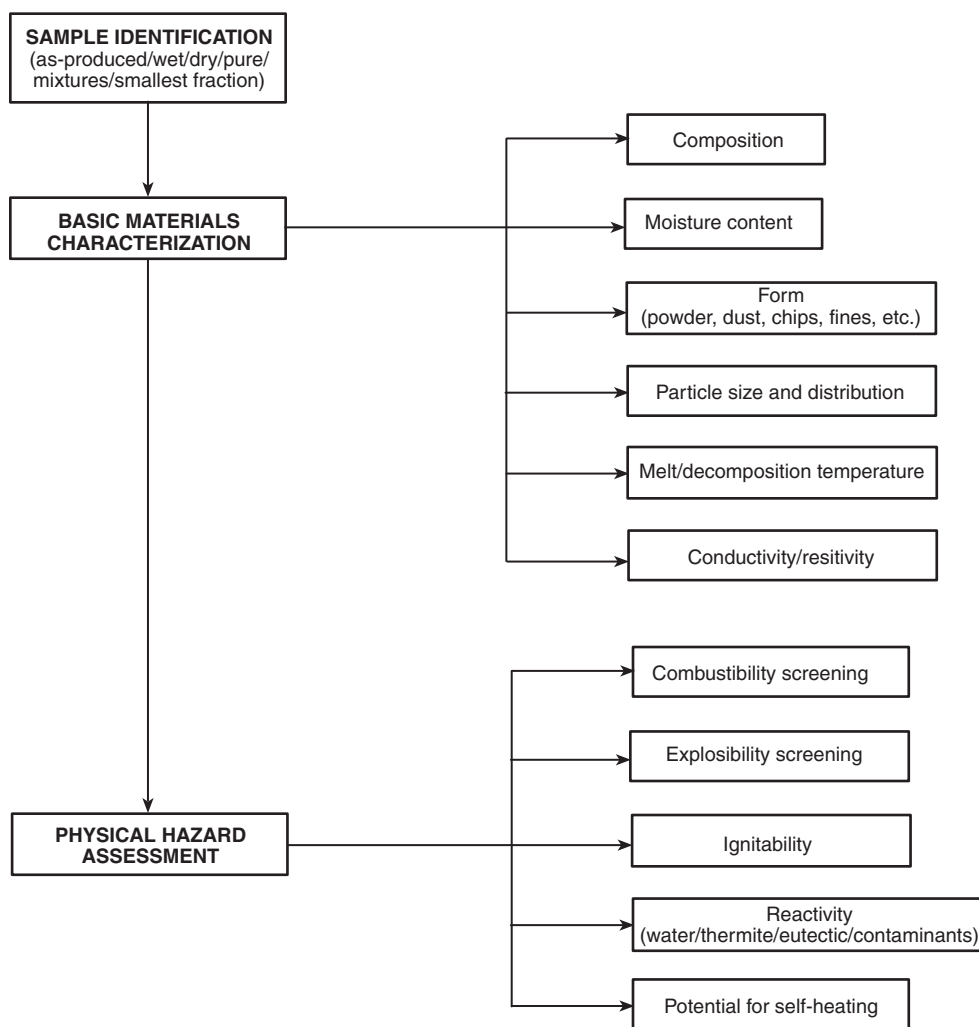


FIGURE A.22.5.2.7.2 Examples of Basic Materials Characterization.

- (b) Particle agglomeration influences including morphology and moisture content

A.22.5.4.1.1 This preliminary screening test used to demonstrate fire risk is the basis for the regulations governing the transport of dangerous goods for United Nations (UN) regulations, DOT, International Air Transport Association (IATA), and the International Maritime Dangerous Goods (IMDG) Code.

The preliminary screening test is conducted in the following fashion:

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

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

A.22.5.4.1.4 Results of the preliminary screening test can have one of the following 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, then 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. A larger scale propagation test could be considered to validate a negative result. Experience with these tests have shown that many metals will just produce glowing with a standard powder train test, yet will produce positive explosibility results in the tests described in Section 5.5 and in non-standardized flash fire tests. Therefore, the powder train tests for materials that glow can result in a misleading representation of the fire and flash fire hazards. Hazards 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 should 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, hazards analysis should focus on additional protocols and compliance with other NFPA standards.

Some nanometal powders, as well as some larger particulate pyrophoric metals, will ignite either on exposure to air or while handling during test preparations. These materials should be considered combustible and are covered by this chapter. One example of a metal that is not combustible in micrometer particle size but can be pyrophoric as a nanometal is copper (*see Krietsch 2015*).

A.22.5.4.1.5 If propagation of the powder train occurs along a length of 200 mm (7.87 in.) in 20 minutes or less, the burning rate test is required. The burning rate test requires specific preparation of the powder sample. The sample is prepared in a specific fixture as shown in Figure A.22.5.4.1.5.

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

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

100 mm² (0.16 in.²). In the case of a moisture-sensitive substance, the test must be carried out as quickly as possible after its removal from the container.

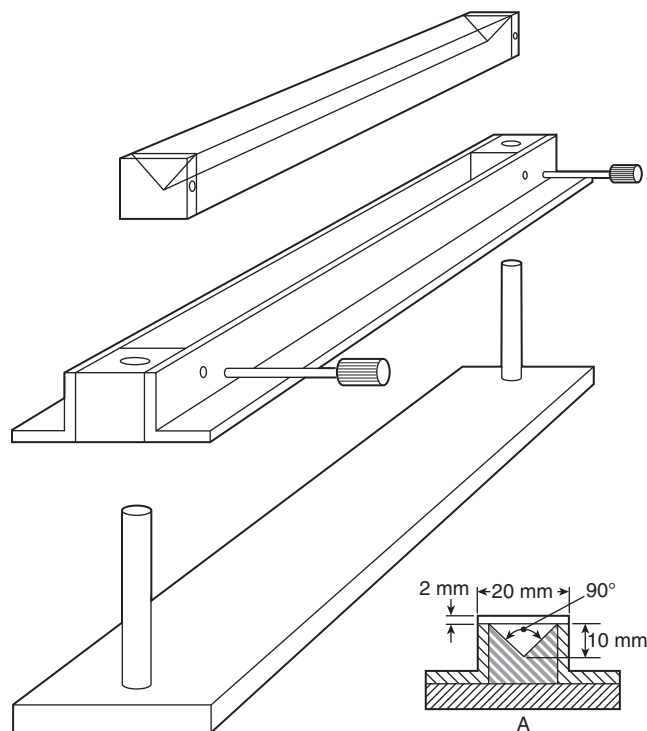
Test conditions are as follows:

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

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

A.22.5.4.1.5.1 The screening test is performed under atmospheric conditions; however, the process might be performed under other conditions, such as elevated temperature, excess oxygen, other gases, hybrid mixture, and elevated pressure, that could influence combustibility.

A.22.5.4.2 The flash fire potential of a metal particulate sample should be assessed using the screening test methodology described in Section 13 of ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. If the explosibility screening tests conducted in accordance with ASTM E1226 produces



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

FIGURE A.22.5.4.1.5 Fixture for Preparation of Sample for Burning Rate Test.

an explosion pressure ratio greater than two, the test material should be considered to have a flash fire potential.

A.22.5.4.3.1 Annex Y gives a small sample of published ignition and explosion data on various sizes of aluminum powders.

A.22.5.4.3.1.1 NFPA 68 includes annex material that explains the need for these additional design requirements. MEC and LOC are also known to be affected by the test chamber volume. If users develop an explosion protection strategy based on 20-L volume data for P_{max} , K_{St} , MEC, and LOC, the protection systems could be improperly sized.

A.22.5.4.3.1.2 Many nanometal samples ignite upon compressed air injection into the ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, test vessel so that it becomes difficult to measure the pressure ratio used as the basis for a positive explosibility determination. (See Bouillard 2010 and Boilard 2013.)

A.22.5.4.3.2 The determination of whether a sample of material is a combustible, explosible dust should be based on the explosibility screening test methodology provided in ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Alternatively, a standardized test method such as ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, can be used to determine dust explosibility.

There is some possibility that a sample will result in a false positive in the 20 L (5.25 gal) sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source over-driving 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 ($\geq 1 \text{ m}^3$) enclosure, which is less susceptible to over-driving.

For some combustible metals, it has been found that the K_{St} and P_{max} values will be higher in a larger scale enclosure. This means that conversely there is some possibility that a sample will result in a false negative in the 20 L (5.25 gal) sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. If a screening test produces evidence of combustion yet a test pressure below the threshold, it is recommended to validate this negative result in the larger scale 1 m^3 enclosure. This possibility is considered more likely for metals with calculated maximum adiabatic flame temperature equivalent to magnesium and higher. NFPA 68 mentions specifically aluminum, hafnium, magnesium, tantalum, and titanium as metals that could exhibit the same phenomena. [See also Table A.22.1.1.3.]

A.22.5.4.3.3 Explosive properties are dramatically affected by changes in physical properties, chemical composition, particle size distribution, amount of fines, and mean particle size. These changes can be due to variations in process operating parameters, substitutions in shop and feedstock supplies, changes to shop supply providers, and process or transport equipment changes including normal equipment wear. Test sample selection should include an assessment of the extent of these nominal process, equipment and material variations in order to select a sample representative of the finest particulates and compositions that are likely to enhance explosibility. If explosibility and particle size variations cannot be assessed without testing, multiple samples should be collected and submitted for testing.

If normal composition of the material includes a high moisture content but subsequent drying or exposure to elevated temperature of the material occurs, it is highly advisable that parallel testing of the material at low moisture content be performed. 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 during packaging, shipping and testing.

A.22.5.4.3.4 Testing for the minimum ignition energy (MIE) of a combustible particulate is carried out in accordance with recognized international standards ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, and BS PD CLC/TR 60079-32-1, *Explosive atmospheres Part 32-1: Electrostatic hazards, guidance*.

The MIE test uses a Hartmann tube vertically mounted with a 63 mm inside diameter and 1 L volume. The Hartmann tube is outfitted with a compressed-air dust dispersion system and brass electrodes. Different types of igniters are used for this test to produce sparks. One type, which uses high-voltage capacitance sparks, can produce sparks of widely varying energy. In the test, a measured weight of the test sample is dispersed through a spark of known energy. The spark energy and the weight of the sample are varied to produce different combinations of dust concentration and spark energy. Normally, the dust concentration is high. The spark energy is reduced until no dust ignition occurs. The value of the spark energy at which ignition ceases is the MIE.

Explosibility Test. The explosibility test serves to identify the maximum unvented deflagration pressure a material is capable of producing under optimum conditions of dust cloud concentration, as well as the maximum speed of the explosion.

This explosion severity test is carried out in accordance with the ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or BS EN 14034-1, *Determination of explosion characteristics of dust clouds — Part 1: Determination of the maximum explosion pressure P_{max} of dust clouds*, and BS EN 14034-2, *Determination of explosion characteristics of dust clouds — Part 2: Determination of the maximum rate of explosion pressure rise $(dP/dt)_{max}$ of dust clouds*.

The test regimen employs a 20 L or larger spherical explosion chamber. For legacy metals and similar alloys or mixtures with adiabatic flame temperatures higher than 3000°C , unless explosibility parameters are determined in nominal 1 m^3 or larger calibrated test vessels, the reported explosibility parameters (P_{max} , K_{St} , MEC, and LOC) might be understated for the application of mitigation design purposes. A sample of the test powder is injected into the sphere using air driven at a force of 20 bar. Ignition is accomplished via the use of two 5 kJ chemical igniters. The test enclosure is partially evacuated so that at the end of the injection, the dust cloud is at atmospheric pressure. The pressure–time history of the explosion event is measured for each test, and the maximum explosion pressure (P_{max}) and the maximum rate of pressure rise $(dP/dt)_{max}$ are determined. A series of these tests are conducted over a wide range of dust concentrations, and the individual maximum values measured are called P_{max} and dP/dt_{max} . The critical tests are performed in triplicate, and the values obtained at the optimum dust concentration are then averaged to obtain P_{max} and dP/dt_{max} . In general, these two concentrations are not the same. The value at which P_{max} occurs is c_{opt} , and the value at which dP/dt_{max} occurs is c_w . In this document, c_w is used to evaluate dust explosion hazard and dust flash fire hazard areas.

From the data for the dP/dt_{max} , the value of K_{St} is calculated. The K_{St} value allows different materials to be compared on an equal basis to determine a relative ranking of explosion risk and consequence. The K_{St} value is obtained by normalizing the maximum value of dP/dt_{max} to a volume of 1 m³. Materials are classified according to the St class system in Table A.22.5.4.3.4. The higher a powder St class number, the more energetic the explosion and the greater the speed of the explosion.

Limiting Oxidant Concentration (LOC) Test. The purpose of the test is to determine the oxygen concentration below which the ignition of the dispersed dust is not possible.

The test is conducted in accordance with ASTM E2931, *Standard Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*, or BS EN 14034-4, *Determination of explosion characteristics of dust clouds — Part 4: Determination of the limiting oxygen concentration (LOC) of dust clouds*.

The LOC test is conducted using a 20 L or larger spherical explosion chamber described for the explosibility test.

The protocol for the LOC test requires pursuing an algorithm for the simultaneous search for the lowest oxygen concentration that can support self-sustaining flame propagation and the optimum powder concentration at the lowest oxygen concentration. Tests are repeated with lower and lower oxygen concentrations (percent by volume) until the lowest level of oxygen capable of supporting explosion is determined.

The “break” point definition of what is and what is not an explosion event has changed over the last decade. Current ASTM and BS EN standards define an ignition as a measured value of pressure during the test that is equal to or greater than 1 bar-g. The results can be quite sensitive to the choice of this threshold value especially in smaller test enclosures.

Minimum Explosible Concentration (MEC) Test.

The test to determine the MEC of a combustible dust is performed using ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, or BS EN 14034-3, *Determination of explosion characteristics of dust clouds — Part 3: Determination of the lower explosion limit (LEL) of dust clouds*.

The test is performed using the 20 L or larger spherical explosion chamber. Testing is performed to determine a nominal dust concentration at which ignition always occurs. The dust concentration is then reduced until no evidence of ignition is found. The threshold-defining point for this test between ignition and no-ignition is a pressure rise of 1 bar-g.

The MEC test is critical for determining the dust loading of dust collection systems as well as determining when fugitive dust accumulation has reached a point where explosion danger is manifest.

A.22.5.6 Many organometallic compounds — also referred to as metal organics — are pyrophoric, react violently with water,

and burn with characteristics similar to combustible metals. Manufacturer safety data sheets for particular organometallic compounds have more specific characterizations of the flammability and reactivity characteristics as well as guidelines on handling, storage, firefighting, and disposal.

A.22.7.1 Metals in a combustible form present three primary hazards, solids in combustible form (e.g., chips, swarf, fines, ribbon, solids or alkali metals), combustible metal dust, and combustible metal in a molten form.

A.22.7.1.1 It is not always possible or practical for existing facilities to be in compliance retroactively with new provisions of a standard on the effective date of that standard. However, a plan should be developed to achieve compliance within a reasonable timeframe.

A.22.7.2.1 See 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.

A.22.7.2.1.2 One method by which the requirement in 22.7.2.1.2 can be satisfied is with a hazards analysis conducted in accordance with the methods outlined in *Guidelines for Hazard Evaluation Procedures*. To determine if a dust deflagration hazard exists, see Figure 22.5.4.3.1.

A.22.7.4 . It is important to evaluate risks of metals in a molten state, given their ability to produce steam and/or hydrogen explosions if contact with water occurs during a process upset or fire suppression operations.

Molten metals present additional hazards of reactivity. A separate hazards analysis of molten metals is necessary to identify and evaluate the unique hazards of fire, reactivity, and explosion presented by their handling and use.

A.22.7.4.2 See A.7.2.2.

A.22.7.5.1(2)(b) See A.7.3.1(2)(b).

A.22.7.5.3.1 See A.7.3.3.1.

A.22.7.5.3.3 See A.7.3.3.1.

A.22.8.4.2.1.1(A) Once ignition has occurred either in a cloud suspension or in a layer, an explosion is likely. Often the initial explosion is followed by another much more violent explosion, fueled by the dust from accumulations on structural beams and equipment surfaces that is thrown into suspension by the initial blast. For that reason, good housekeeping in all areas that handle dust is vitally important.

A.22.8.4.2.1.1(B) There have been several proposed methods for determining an appropriate threshold value for fugitive dust accumulations. It should be noted that some methods might not be appropriate in all situations.

A.22.8.4.2.2 Permanently installed vacuum cleaning systems provide maximum safety because the dust-collecting device and the exhaust blower can be located in a safe location outside the dust-producing area and the air-material separator (AMS) can be properly protected from deflagration hazards.

A.22.8.4.2.2.1(B) Portable vacuum cleaners are self-contained units having a vacuum source created either by the combination of compressed air and a venturi or by a suitably classified

Table A.22.5.4.3.4 Explosive Energy Classification

St Class	K_{St} (bar-m/sec ¹)
St 1	>0–200
St 2	201–300
St 3	>300

electrical AMD, as well as an AMS that is either dry or wet. (See also 8.4.2.2.)

A.22.8.4.2.2.3 It is recommended that no more than 5 lb (2.2 kg) of dust should be collected at any one time before a vacuum is emptied. A vacuum cleaner should be checked to be sure that it is empty before each use. A vacuum cleaner should be emptied after each use. Additionally, if filter media is used, check it for blinding, and it might need to be replaced should an incompatible material be filtered.

Improper use of vacuum cleaners for combustible metal powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77. Utility vacuums or residential, automotive, hobby, or household portable vacuums should not be used.

A.22.8.4.2.2.4 See NFPA 77.

A.22.8.4.2.2.4(A) If equipment has an integral grounding plug or system, verification of the equipment condition is sufficient.

A.22.8.4.2.2.7 For example, iron oxide dusts are known to be incompatible with titanium, aluminum, magnesium, and other metal dusts due to the potential for an exothermic thermite reaction (see A.3.3.76 for additional information). If filter media is used, it should either be replaced or tested to confirm it will still allow for adequate airflow for vacuum cleaning. The unit should be cleaned unless it has been determined that the materials exhibit no incompatibility.

A.22.8.4.2.2.10 These listing standards are common throughout the industry and it is possible for manufacturers to configure these devices to be suitable for housekeeping of combustible dust. Not all devices manufactured to these standards are suitable for combustible dust, and the manuals and manufacturer's guidance around the acceptability for combustible dust must be adhered to.

A.22.8.4.2.6.2(4) The discharge pressure 30 psi (207 kPa) is in accordance with OSHA requirements in 29 CFR 1910.242(b), "Hand and Portable Powered Tools and Equipment, General."

A.22.8.4.6.1 A relatively small initial dust explosion will disturb, and suspend in air, dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary explosion, which usually causes the major portion of the damage. Reducing dust accumulations is, therefore, a major factor in reducing the hazard in areas where a dust hazard can exist.

Where the underlying surface color is no longer discernible beneath the accumulated dust layer, this can be sufficient to warrant immediate cleaning of the area. Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential. Consideration should be given to dust that adheres to walls, because it is easily dislodged.

Attention and consideration should also be given to other projections, such as light fixtures, that can provide surfaces for dust accumulation.

A.22.8.5 Attention is called to the hazardous conditions that could exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around metal powder plants.

A.22.8.5.7 In NFPA 499, 5.1.6.4 provides an alternative protection approach for certain portable electronic products powered by batteries or photovoltaic cell(s) in accordance with ISA-12.12.03/UL 121203, *Portable Electronic Products Suitable for Use in Class I and II, Division 2, Class I, Zone 2 and Class III, Division 1 and 2 Hazardous (Classified) Locations*.

UL 121203 addresses the necessary criteria, testing, and certification for the use of both body-worn and handheld portable electronic products in hazardous (classified) locations. Body-worn products include devices such as, but not limited to, hearing aids, watches, and smartwatches. Handheld products include devices such as, but not limited to, calculators, some medical injection devices, cellphones, tablet personal computers, and electronic cigarettes (vaping devices).

UL 121203 requires a specific drop test for some devices. Ensuring a device is turned off or not in use does not remove the potential for an ignition.

A.22.8.6 Flash fire-resistant garments are significantly more effective than ordinary clothing in preventing burn injury on exposure to low to moderate heat fluxes, but they cannot prevent burn injuries to personnel immersed in combustible metal flash fires. (See the US Chemical Safety Board's case study report on the Hoeganaes Corporation's fatal flash fires.)

A.22.8.6.2.2 Primary PPE for molten metals would normally be expected to be worn by personnel working near operational foundry furnaces and metal casting areas. Primary PPE for dust flash fires would normally be expected to be worn by personnel working with or near equipment and storage vessels/silos containing powdered metals, and by personnel responsible for maintenance or repairs of combustible metal dust handling or storage equipment (such as dust collectors) and open top containers. This would also include personnel responsible for cleaning combustible metal dusts.

A.22.8.6.3 Testing has shown that the 84 kW/m² (2.0 cal/cm²·sec) heat flux used in the NFPA 2112 garment-equipped mannequin flash fire test is only 25 percent to 32 percent of an iron dust flash fire heat flux. Other combustible metals have higher flame temperatures that can produce even higher heat fluxes. Therefore, the NFPA 2112-compliant garments are not expected to protect personnel against large, extended duration, flash fires involving combustible metal dusts. More stringent flame-resistant garment requirements, such as those for firefighting application in NFPA 1971 and for arc flash protection in ASTM F2621, *Standard Practice for Evaluating Response Characteristics of Safety Products in an Electric Arc Exposure*, might provide better protection for metal dust flash fires, but there is no test data to substantiate their performance for metal dust fires.

A.22.8.6.6.3 Performance requirements described in ASTM F1002, *Standard Performance Specification for Protective Clothing and Materials for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*, for primary protective clothing include the following considerations:

- (1) Fabric flammability, before and after 25 cycles of washing or dry cleaning

- (2) Fabric strength
- (3) Fabric adhesion
- (4) Molten metal shedding when tested using ASTM F955, *Standard Test Method for Evaluating Heat Transfer through Materials for Protective Clothing Upon Contact with Molten Substances*
- (5) Heat transfer through fabric

There are also requirements to cover potentially exposed areas as completely as possible, to not contain external pockets (that could collect and retain molten materials), to not interfere with work function, and to be easily removable. There are also requirements to cover potentially exposed areas as completely as possible, to not contain external pockets (that could collect and retain molten materials), to not interfere with work function, and to be easily removable.

A.22.8.6.7.4 Wool, silk, or synthetic fabrics that can accumulate high static electric charges should not be used in areas containing metal dusts with such low MIE values.

A.22.8.6.7.5.1 Burning combustible metals will burn through material used in the construction of most firefighter protective clothing. Some features (e.g., heavy quilted linings, aluminized outer shells) can reduce this risk. The self-contained breathing apparatus (SCBA) facepiece eye protection worn by firefighters adequately protects against the effects of a lithium fire, with the exception of the intense light given off by burning lithium. (See *NFPA 1500*.)

Specific testing indicates that white-light levels emitted from burning lithium exceed recommended levels, and extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes. A clip-on adapter over an SCBA facepiece with a shaded glass lens equivalent to a No. 6 welding lens has been used successfully to reduce such hazards. A darker lens tends to obstruct the firefighter's view to an unacceptable degree.

A.22.8.8.2 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.

A.22.8.8.2.1 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, flash fires, and 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.22.8.8.3 Emergency preparedness plans for alkali metals should pay special attention to the extreme hazards associated with alkali metals–water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning alkali metals are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent alkali metals fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with alkali metals know its hazards. Such personnel will have the greatest chance to extinguish an alkali-metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

An alkali metal at room temperature in the presence of incompatible materials can reach its melting point and its auto-ignition temperature.

The degree of reaction and the amount of time to produce the melting point and autoignition temperature vary with conditions surrounding the fire, with the temperature of the exposed alkali metals being the major factor. At low temperatures or temperatures within a few degrees of an alkali metal's melting point, the reaction is slower with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting an alkali-metals fire, it is very important that firefighters be aware of the dangers of burning alkali metals. When molten alkali metal reacts with materials such as water or ignitable (flammable or combustible) liquids or gases, molten alkali metals can be ejected for a considerable distance. The severity of alkali-metal reactions varies with a multitude of conditions.

Residues of alkali metals that have been in contact with moisture and air are alkali-metal hydroxides and alkali-metal oxides, which will cause caustic burns when in contact with the skin or eyes. Personnel must wear adequate caustic-resistant PPE when handling residues from alkali metal fires.

A.22.8.9 Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps, professional licenses, and so forth.

A.22.9.3.6 These facility design requirements are in addition to those in 22.16.2, 22.17.2, and 22.18.2. Consideration should be given to automatic fire detection systems in facilities handling metals in combustible form.

A.22.9.3.6.3.2(A) The requirement for watertight roof decks is an effort to ensure that buildings are designed and maintained to minimize possible leaks from weather conditions. Special care should be given to maintaining these roofs, especially in climates where heavy amounts of snow are expected.

A.22.9.3.6.3.3(G) Where surfaces on which dust can collect are unavoidably present, they can be covered by a smooth

concrete, plaster, or noncombustible mastic fillet having a slope sufficient to prevent accumulation. An angle greater than the angle of repose is recommended.

A.22.9.3.6.4 A ridged or peaked roof that allows for natural ventilation of hydrogen is recommended.

A.22.9.3.6.5.1 The need for building deflagration venting is a function of equipment design, particle size, deflagration characteristics of the dust, and housekeeping. As a rule, deflagration venting is recommended unless it can be reasonably ensured that hazardous quantities of combustible and dispersible dusts will not be allowed to accumulate outside of equipment.

Where building deflagration venting is needed, locating the operation in an open structure or in a building of damage-limiting construction is the preferred method of protection. Damage-limiting construction involves a room or building designed such that certain interior walls are pressure resistant (i.e., can withstand the pressure of the deflagration) to protect the occupancy on the other side, and some exterior wall areas are pressure relieving to provide deflagration venting. It is preferable to make maximum use of exterior walls as pressure-relieving walls (as well as the roof, wherever practical), rather than to provide the minimum recommended. Further information on this subject can be found in NFPA 68.

Deflagration vent closures should be designed such that, once opened, they remain open to prevent failure from the vacuum following the pressure wave.

A.22.9.3.6.5.3 For further information, see NFPA 68.

A.22.9.3.6.5.6 For information on deflagration venting, see NFPA 68.

A.22.9.3.6.6 For information on static electricity, see NFPA 77.

A.22.9.3.7.3.3 In some metal processing operations, the process equipment requires cooling water. Under these circumstances, a hazard operations review should be conducted at the sites and locations to determine where to feed the water. Water pipes necessary for providing cooling water should be located to minimize their exposure to areas where the risk of metal fires is possible. It is recognized that metal powders can be ignited by exposure to hot surfaces. As such, the use of cooling water in a judicious manner is a means by which hot surfaces can be reduced or eliminated.

A.22.9.4 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. 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.22.9.4.3.2.1(C) For more information on static electricity, see NFPA 77.

A.22.9.4.3.2.1(D) Any moisture entering the system can react with most metal powders, generating heat and hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.22.9.4.3.2.2(A) Metal and metal alloy powders are produced by various processes. These processes, as well as certain finishing and transporting operations, tend to expose a continuously increasing area of new metal surface. Most metals immediately undergo a surface reaction with available atmospheric oxygen, forming a protective coating of metal oxide that serves as an impervious layer to inhibit further oxidation. This reaction is exothermic.

If a fine or thin, lightweight particle having a large surface area of new metal is suddenly exposed to the atmosphere, sufficient heat will be generated to raise its temperature to the ignition point. Completely inert gas generally cannot be used as an inerting medium, since the metal powder would eventually, at some point in the process, be exposed to the atmosphere, at which time the unreacted surfaces would be oxidized; enough heat would be produced to initiate either a fire or an explosion.

To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces is provided by regulating the oxygen concentration in the inert gas. The mixture serves to control the rate of oxidation while materially reducing the fire and explosion hazard. A completely inert gas can be used if the powder so produced will not be exposed to air in future handling.

A.22.9.4.3.2.2(C) Oxygen limits of 3 percent to 5 percent have been maintained in aluminum powder systems using a controlled flue gas. Other limits are applicable where other inert gases are used. See US Bureau of Mines publication RI 3722, "Inflammability and Explosibility of Metal Powders."

A.22.9.4.3.2.2(D) A completely inert gas can be used if the powder so produced will not be exposed to air in future handling. Metal powder produced without oxygen is more highly reactive than metal powder produced by conventional means.

A.22.9.4.3.2.2(F) Condensing moisture can cause material to stick to ducts and can exothermically react with most combustible metals generating hydrogen.

A.22.9.4.3.2.2(G) Condensing moisture might cause material to stick to ducts and can exothermically react with most combustible metals, generating hydrogen.

A.22.9.4.3.2.2(H) Typically, the minimum conveying velocities range from 3500 ft/min (1078 m/min) to 4500 ft/min (1372 m/min) depending on the material being conveyed. For further information, refer to the ACGIH's publication, *Industrial Ventilation — A Manual of Recommended Practice*.

A.22.9.4.3.3 The following are the two generally recognized methods of separating combustible metal dust in industrial dust collection systems:

- (1) Wet-type air-material separator (AMS) that uses liquid for air-material separation and that is located indoors near the point of dust generation
- (2) Dry-type AMS that uses filter bags or cartridge media for air-material separation and that should be located

outdoors as close as possible to the point of dust generation

A dry-type AMS is not recommended for niobium or tantalum dust. There are some specialized applications where an indoor dry-type AMS can be used for the collection of metal dusts when a wet-type AMS or an outdoor dry-type AMS are not feasible.

Dust collection systems use air or inert gases (rare but feasible conditions) to convey combustible dusts from one location to another, a process that is similar to that of pneumatic conveying/transfer and centralized vacuum cleaning systems. However, dust collection system design uses design parameters that are significantly different from pneumatic conveying/transfer and centralized vacuum cleaning systems. For example, a typical dust collection system does not consider dust loading in the design calculations because the mass of air or gas is much greater than the collected dust particle mass loading. However, pneumatic conveying/transfer and centralized vacuum cleaning systems must consider the expected material mass loading in the design calculations.

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, assuming proper design and operation.

For guidance on the designing, acquisition, operation, and maintenance of dust collection systems, refer to the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice*, and A.22.9.4.3.3.1.

A.22.9.4.3.3.1 Subsection 22.9.4.3 covers requirements for dust collection systems intended to convey and collect fugitive dust. Generally, fugitive dust is created by machining, fabricating, finishing, bulk-handling, and other dust-generating operations or consists of powder that have escaped from a process. Powders are particles of matter intentionally manufactured to a specific size and shape and are typically handled in processing equipment systems.

With regards to 9.4.1.2, dust collection systems are designed for specific conveying, air distribution, and minimum duct velocity 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.

With regards to 9.4.3.1.1, metal dusts or particles, due to their density, deflagration hazard, or both, require higher-than-normal conveying velocities to ensure adequate conveying velocities. Most applications should use 4500 ft/min (1372 m/min) or higher to maintain conveying velocities, especially for more complex systems, longer duct runs, and multiple turns. Abrasive wear must also be considered, so a maximum velocity in the 5500 to 6000 ft/min (1676 to 1829 m/min) range is typically recommended. Higher velocities also allow for unknown upset conditions but do require additional energy (i.e., static pressure) to achieve the desired results. Further information can be obtained by referring to the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice*.

With regards to 9.4.3.3.6, a dry-type AMS often cannot be used with combustible metal dusts. This is due mainly to the

inherent operation of such a device and the tendency of combustible material to accumulate inside the unit. A wet-type AMS unit uses a liquid to “capture” and separate the dust from the air or gas stream. This “quenching” of the dust particles (i.e., wetting) inherently reduces risks as long as the device operates properly. Proper selection of the AMS for a dust collection system with combustible metal dusts is critical to the safe operation of the system.

A.22.9.4.3.3.5 There are two general methods of combining dust sources (i.e., hoods): the tapered main approach and the plenum approach. The tapered main approach or plenum method gradually gets larger as additional airflows (i.e., dust sources) are merged, which assures duct velocities are kept nearly constant. A plenum method of combining dust sources does not maintain velocities at all locations because a general, much larger duct is used as a plenum or connection point for a series of smaller ducts from the dust sources. This results in portions of the plenum where low duct velocities occur that allow accumulation of materials. These low duct velocities upstream of the subduct entrance occur whether the entrance is angled or perpendicular to the plenum. The plenum method is not recommended for dust collection system design for combustible solids. See Figure A.22.9.4.3.3.5(a) and Figure A.22.9.4.3.3.5(b) for illustrations of both methods.

A.22.9.4.3.3.6 Examples of spark-producing dust sources include, but are not limited to, metal grinding, polishing, and cutting/sawing. The purpose of this section is to require segregation/isolation of equipment-generated dust sources, where such ignition sources are produced, from those that are not. This also includes the requirement to isolate such ignition sources from other recognized ignition sources.

A dry-type AMS requires one or more devices between it and the ignition-producing source to mitigate the hazard because its operation inherently creates an environment with a high risk of explosion. A wet-type AMS provides for the quenching of such ignition sources and reduces the risk of explosion.

Where proper isolation of ignition sources is not feasible, a separate, independent dust collection system with a wet-type AMS for each individual ignition source would be the recommended solution.

For active mitigation systems, system certification can provide support for their use with legacy metals. See 22.9.8.2.

A.22.9.4.3.3.7 The majority of dust collection systems use centrifugal-type fan packages for inducing the air/gas flow through the system. However, certain types of systems, such as high-velocity, low-volume (HVLV) and venturi-type scrubber systems, might require higher differential pressures that require other types of fans or pressure blowers. Various models are available that will provide the performance characteristics required. Care must be taken to consider the worst-case design situation, such as when the dry-type dust collector filters are nearly blinded or the scrubber requires its maximum differential pressure. Drive motor sizing should also consider when the system is operating with minimal pressure requirements across the AMS, such as when the filters are new and at low resistance to flow.

A.22.9.4.3.3.8 The optimal location of the fan package (or pressure blower used to create the vacuum) is on the clean side of the dry or wet AMS. This is valid whether the material/dust is combustible or not. This is also optimum for safety considera-

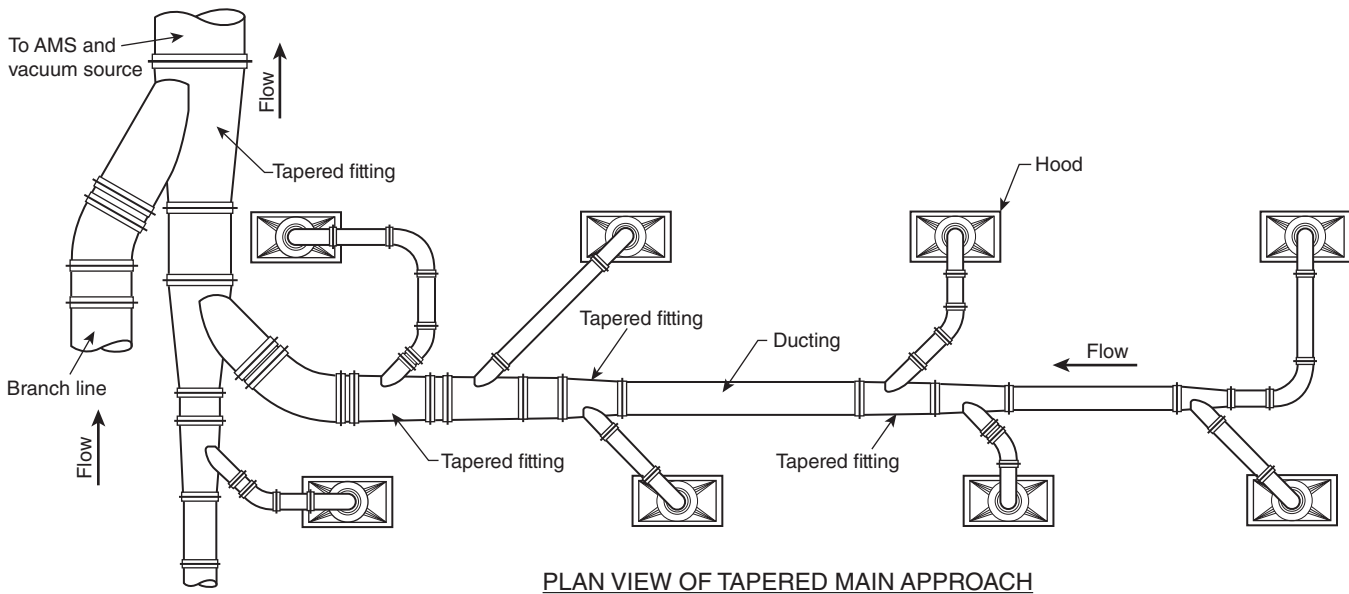


FIGURE A.22.9.4.3.3.5(a) Tapered Main Approach.

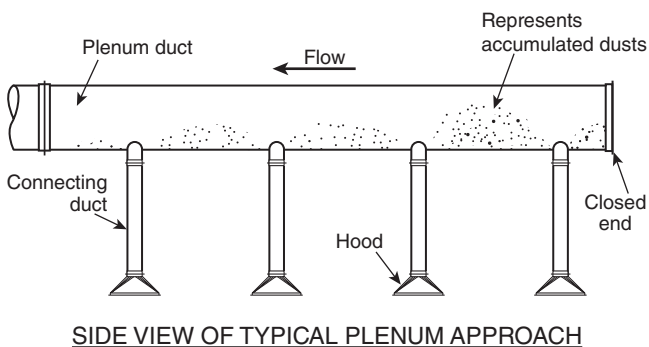


FIGURE A.22.9.4.3.3.5(b) Plenum Approach.

tions because the fan package can be a significant ignition source and deflagration risk (e.g., due to bearing failure, drive failure, impeller imbalance, friction, wear) when located in the dirty air/gas stream.

A.22.9.4.3.3.9 The importance of locating the control and monitoring equipment where personnel operating the system are safe can be illustrated by the following condition in addition to that in A.9.4.3.1.2:

- (1) Where there is no explosion protection for the dust collector, the personnel operating the controls and monitoring equipment would potentially be at risk.

A.22.9.4.3.3.10 Typical margins of safety used for pneumatic dust handling are 25 percent to 50 percent of the MEC. MEC data for some metals with varying particle size distributions can be found in US Bureau of Mines publication RI 6516, "Explosibility of Metal Powders." Although the combustible metal powder-air suspension can be held below 25 percent to 50 percent of the MEC in the conveying system, the suspension will, of necessity, pass through the explosible range in the AMS unless the dust is collected in liquid, such as in a wet-type AMS.

A.22.9.4.3.3.11 For example, a warning label for steel should state the following:

DANGER — THIS DUST COLLECTION SYSTEM IS FOR COLLECTION OF STEEL ONLY.

COLLECTING ANY OTHER MATERIAL CAN CREATE ADDITIONAL FIRE OR EXPLOSION HAZARDS.

A.22.9.4.3.3.13 Due to ambient temperatures, air/gas temperatures in the area, or other reasons, it is possible that condensation could occur in either the ducting, the AMS, or both. This would create conditions where accumulations can occur (and dry out later, creating an unknown hazard), even with proper duct velocities, or can create unwanted chemical reactions with some of the combustible metal dusts. Insulation, use of heated air/gas, and other methods can be used to mitigate this situation.

A.22.9.4.3.3.14 For more information on static (i.e., electrostatic) electricity, see NFPA 77.

A.22.9.4.3.3.15(A) A continuous path to ground must be maintained to avoid static charge accumulation resulting in a potential ignition source. Examples of losing path to ground could include losing the neutral on the electrical circuit. The sharing of a common grounding source has the potential of energizing the system that is being protected from static electricity. See NFPA 77, Annex G, for examples of bonding and grounding systems.

A.22.9.4.3.3.15(C) It is critical that the continuity of the grounding and bonding of the entire dust collection system be checked, verified, and documented on a periodic basis. This check should be done at least annually, but might require additional periodic checks due to operating conditions, changes, and so on.

A.22.9.4.3.4 A centralized vacuum cleaning system consists of multiple hose connection stations interconnected by a tubing or piping network to an AMS (dry or wet) and then to a vacuum producer (typically a centrifugal exhauster or PD

blower). A cyclone AMS can be added but is not needed in most cases because the main AMS, such as a filter receiver or wet-type receiver, is usually designed to accept the full rate of material/dust from the vacuum cleaning operations. A single operator up to many simultaneous operators can use the system depending on the design parameters.

Air is the only gas that is used for pneumatic conveying/transfer as there is no practical way to use inert gases. This, and the fact that the system will vacuum anything that will fit in the hose, makes this type of system a high deflagration risk. This system, whether existing or new, should always be part of the DHA.

Permanently installed vacuum cleaning systems are preferred to portable vacuum systems because they provide a controlled method for removing the combustible metal dust accumulations and for transferring them to a location where the hazards can be controlled or mitigated.

See Figure A.22.9.4.3.4 for typical components of a centralized vacuum cleaning system.

With regards to 9.4.1.2, centralized vacuum cleaning systems are designed for specific vacuum cleaning 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.

With regards to 9.4.3.1.1, It is recommended that no more than two simultaneous operators (i.e., hose connection or vacuuming stations) be allowed on any one line to the AMS (e.g., filter receiver if dry or wet receiver). This is to assure that adequate conveying velocity can be maintained with just a single operator on the same line. This is necessary to avoid the situation when a single operator is on a system where large diameter piping is used to allow for multiple simultaneous operators (i.e., three or more), which would result in conveying velocities below what is necessary to keep the conveyed material airborne and moving.

A.22.9.4.3.4.1 The minimum required velocity will depend on the operational design parameters. Such parameters include, but are not limited to, the hose length and diameter, type of vacuum tools used, number of simultaneous operators (from a single to many), and conveying distances. A worst-case approach should be used to ensure that the system operates properly at all times (e.g., considering the velocity in the piping/tubing with a single operator cleaning up a major spill).

A.22.9.4.3.4.2 Since most metal dusts are sensitive to electrostatic discharges, it is critical that proper grounding and bonding be achieved with all vacuum tools used.

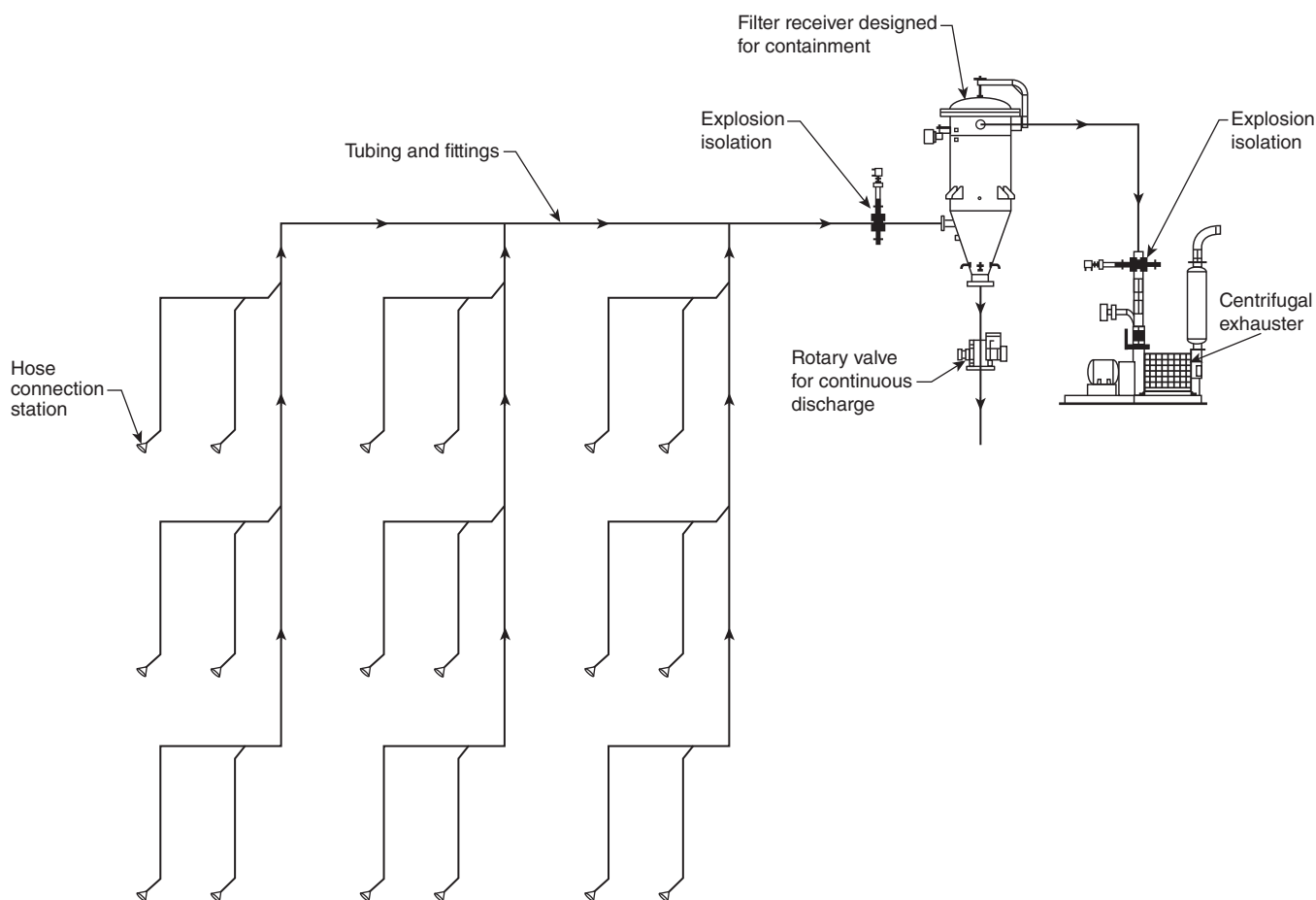


FIGURE A.22.9.4.3.4 Typical Components of a Centralized Vacuum Cleaning System.

A.22.9.4.3.4.4 For information on static electricity, see NFPA 77.

A.22.9.4.3.4.5 No PVC or similar tubing or piping should be used because such materials will accumulate electrostatic charges and create unacceptable risks. Commercially available tubing and piping is available specifically for centralized vacuum cleaning systems. Belled male-female connections should be avoided due to the difficulty in assuring proper grounding and bonding (i.e., continuity). Direct grounding/bonding of the connections should include wired connections or other methods verified as effective through testing.

A.22.9.4.3.4.6 The AMS used in the system is basically a dust collector used at a higher vacuum (i.e., negative pressure). Therefore, it is the intent of this requirement to have the AMS used comply with all the pertinent portions of the dust collection sections where the AMS is discussed.

A dry-type AMS will typically have higher risks than a wet-type AMS when used with vacuum cleaning systems due to the inherent methods of operation. However, it is necessary to consider all the metal dust characteristics before selecting an AMS for the application.

A.22.9.4.3.4.7 Dry-type AMS units are not storage hoppers and require the collected material be continuously discharged to a properly designed container.

The device or devices used to provide this continuous discharge must be designed specifically to handle the combustible metal dusts involved and the associated risks.

A.22.9.4.3.5 A high-efficiency, cyclone-type collector presents less of a hazard than a bag- or media-type collector and, except for extremely fine powders, will usually operate with fairly high collection efficiency. Where cyclones are used, the exhaust fan discharges to atmosphere away from other operations. It should be recognized that there will be some instances in which a cyclone collector can be followed by a fabric-, bag-, or media-type collector or by a scrubber-type collector where particulate emissions are kept at a low level.

The hazards of each type of collector should be recognized and protected against. In each instance, the fan will be the last element downstream in the system. Because of the extreme hazard involved with a bag- or media-type collector, consideration should be given to a multiple-series cyclone with a liquid final stage.

Industry experience has clearly demonstrated that an eventual explosion can be expected where a bag- or media-type collector is used to collect combustible metal fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances when it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag- or media-type collector. With the knowledge that strong explosive potential is present, the producer will locate the bag- or media-type collector a safe distance from buildings and personnel.

If a bag- or media-type collector is used, the shaking system or dust-removal system can minimize sparking due to frictional contact or impact. Pneumatic- or pulse-type cleaning is more desirable because no mechanical moving parts are involved in the dusty atmosphere. If the bags are provided with grounding wires, they can be positively grounded through a low-resistance path to ground. Where bags are used, it is customary that the

baghouse be protected by an alarm to indicate excessive pressure drop across the bags. An excess air-temperature alarm is also frequently employed.

A bag- or media-type collector is customarily located at least (50 ft (15 m) from any other building or operation. It is not customary to permit personnel to be within 50 ft (15 m) of the collector during operation or when shaking bags. Deflagration vents are usually built into the system, as described in NFPA 68. Care should be exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.22.9.4.3.5.1(B) The blank is provided for segregation and must be removed before restoring the equipment to operation.

A.22.9.4.3.5.3 Some collector bags or other types of media or screens have fine, noninsulated wire enmeshed into, woven into, or otherwise fastened to the cloth. These items are always securely grounded. It should be pointed out that grounding is not a positive guarantee of static charge removal because there is no dependable force to cause the charges to move across the nonconducting area of the fabric to the grounded wires. Often, a substantial potential difference can be measured. Also, it is possible that a wire in the cloth could break in such a way that it is no longer grounded. Such a wire serves as a capacitor and could store a static charge.

A.22.9.4.4.2 A dry-type air-material separator (AMS), as the name implies, does not use any liquids to separate the dust from the airflow. This device includes, but is not limited to, cyclones (i.e., centrifugal collectors), bag or cartridge filter dust collectors, electrostatic collectors, and final or HEPA filters.

Cyclones separate the entrained dust from the air or gas flow by centrifugal, inertial, and gravitational forces. The effectiveness of a cyclone is based on the dust characteristics, physical configuration of the cyclone, inlet velocity and velocity through the cyclone, and dust loading (i.e., weight of dust per mass flow of air or gas, usually in grains per cubic foot). Cyclone efficiency can range from the collection of only large particles to 10 μm and less. However, no cyclone is 100 percent efficient, and even the ultra-high-efficiency designs will have some percentage of dusts below 10 micron passing through. Cyclones can be used to remove heavy dust loadings of large particles prior to a secondary AMS (dry or wet) where this proves beneficial. However, this combination requires more energy and more costs, and might be unnecessary. The main advantage of using a cyclone in place of a filter-type or wet-type AMS is the reduced maintenance, the reduced hazardous conditions associated with filter-type dust collectors, or both. If combustible dusts are involved, the cyclone will likely require deflagration protection and isolation.

Filter bag dust collectors are the most common dry-type AMS units, although cartridge filter AMS units are also used for many dust collection applications. Other than the type of filter media used, the main difference between the devices is the method of providing automatic filter cleaning. By far the most common and proven method is called pulse-jet or reverse-pulse-jet, where compressed air is blown at timed intervals back through the filter media (reverse to the system airflow) to clean the filters. Other methods include reverse-air [which uses a fan or positive displacement (PD) blower to provide reverse airflow to a rotating arm above the filters] and shaker (motor and cam shake the filters when isolated from the airflow) methods. The pulse-jet method has the advantages of no moving parts in the

air stream, less complexity, and typically reduced ignition-source risk.

Electrostatic AMS devices use electrical charges to attract dust particles to plates. This approach is not recommended for metal dusts, and it is not allowed for combustible metal dusts.

Final or high-efficiency particulate arrestor (HEPA) filters are normally used as secondary AMS units after a primary dry-type AMS when the air/gas flow is to be returned (e.g., to the building). These cartridge filter media devices are highly efficient at collecting particles below 10 μm but are limited in their use since they can tolerate only very light dust loadings. They should not be used where pyrophoric combustible metal dusts are involved, as accumulations could lead to hazards (e.g., ignition). These dry-type filters have only limited use with metal dusts.

The hazards of each dry-type AMS should be recognized, and protection against the hazards should be provided. Metal industry experience has demonstrated that the risk of an eventual explosion is high where a bag or cartridge AMS is used to collect combustible metal fines. When these dry-type AMS units are used, they should be located a safe distance from buildings and personnel.

See Figure A.22.9.4.4.2(a) through Figure A.22.9.4.4.2(d) for examples of dry-type AMS.

A.22.9.4.4.2.1 Historical data show that the application of effective explosion suppression, explosion isolation, and deflagration venting is difficult for many combustible metal dusts with a K_{St} greater than 150 bar-m/s. More recent data show that advances in equipment design have demonstrated the ability to protect dusts greater than 150 bar-m/s. However, the ability to effectively protect high K_{St} dusts is largely dependent on the properties of the dust, process in which the dust is being handled, and size of the equipment (e.g., collector, duct). For this reason, it is important to base the protection's ability on the actual dust and process under review.

A.22.9.4.4.2.2(1) The 30 mJ limitation is consistent with IEC 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance*. Environmental permits might require more efficient filtration than can be achieved with the currently available

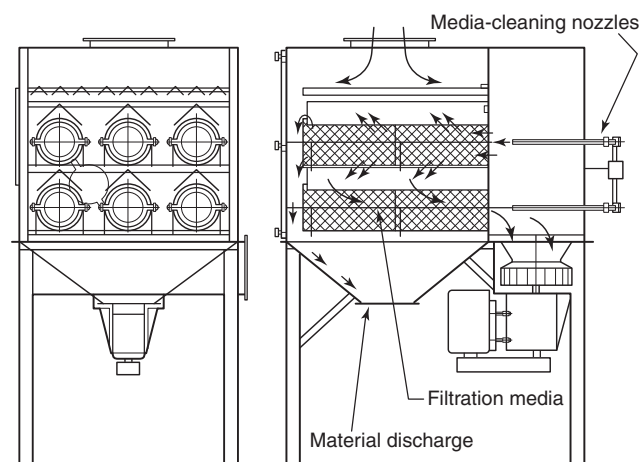


FIGURE A.22.9.4.4.2(a) Typical Downflow Cartridge Dry-Type AMS.

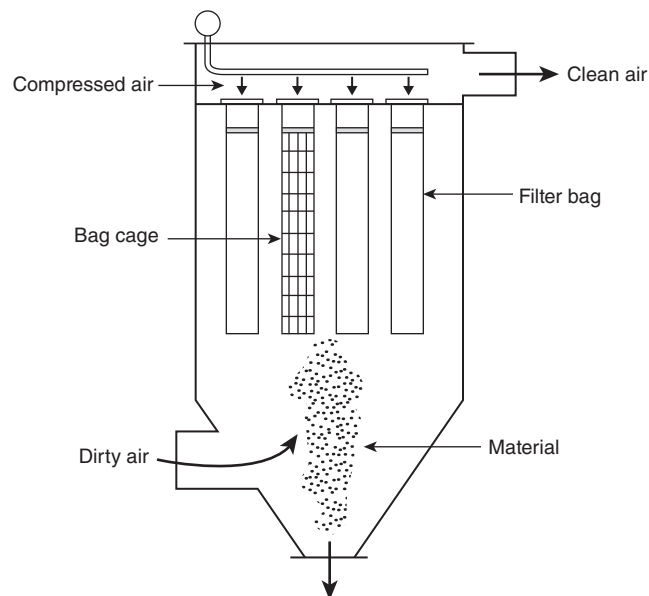


FIGURE A.22.9.4.4.2(b) Typical Pulse-Jet Dry AMS/Dust Collector.

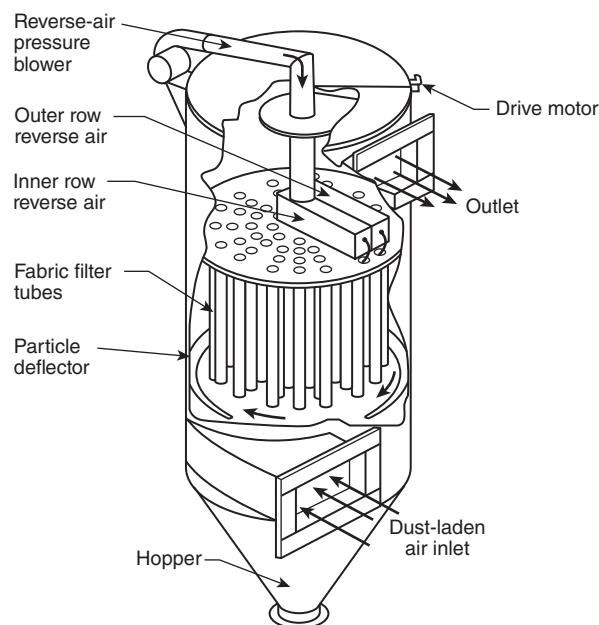


FIGURE A.22.9.4.4.2(c) Typical Reverse-Air Dry AMS/Dust Collector.

static dissipative filter media. See A.22.9.4.3.5.3 for information on the concerns with static dissipative filter media.

A.22.9.4.4.2.2(2) Accumulations on filter media should be limited to levels below the thresholds for any oxidative self-heating ignition and any possible ignition due to exothermic reaction with humid air. These thresholds should be determined as part of the dust collection dust hazards analysis (DHA) conducted in accordance with Chapter 7 and Section 22.7.

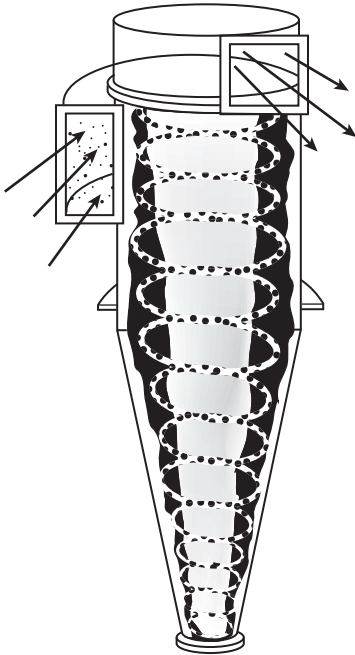


FIGURE A.22.9.4.4.2(d) Typical Cyclonic AMS.

A.22.9.4.4.2.3 Condensing moisture might cause material to stick to interior surfaces and can exothermically react with most combustible metals generating hydrogen.

A.22.9.4.4.2.4(A) Electrostatic collectors inherently introduce a potential ignition source based on their method of operation.

A.22.9.4.4.2.4(C) The concern is that collected dust and filter media are close to the operator; hot embers from operations like grinding could ignite the collected dust and filter media and expose the operator to a flash fire. Wet dust collectors or external dust collectors located a safe distance away from the downdraft table should be used. A DHA could identify circumstances where it would be acceptable to use a self-contained downdraft table with additional protection methods.

Examples of environmental control booths are buffing, grinding, and finishing booths.

A.22.9.4.4.2.4(D) Examples of environmental control booths are buffing, grinding, and finishing booths.

A.22.9.4.4.2.4(F) The purpose of this requirement is to ensure that a metal fire is contained within the equipment.

A.22.9.4.4.2.5 A coating of fine dusts will always occur inside the AMS and on any filter media (if used). The purpose of the requirement is to not allow accumulations of combustible dusts inside the AMS other than the normal operating conditions. An AMS should not be used as a storage hopper. Rectangular dry-type media AMS will tend to accumulate significant dust accumulations on ledges and other surfaces. This is to be avoided where feasible by the use of cylindrical units or designs where this accumulation is limited.

A.22.9.4.4.2.7(B) The construction of a cyclone dry-type AMS handling metal powders or metal dusts should limit buildup of materials within the cyclone to levels below the threshold for any oxidative self-heating ignition and any possible ignition due to exothermic reaction with humid air.

A.22.9.4.4.2.8(A) Fire detection and alarm devices should provide the earliest possible warning of a developing fire. Metal flames are so hot that the filter media will burn through quickly so that a broken bag detector in the clean exhaust could be the fastest form of fire detection. Multiple sensors or devices might be required due to the physical size of the collector or other requirements.

A.22.9.4.4.2.9 The following is an example of the required equipment for and the steps of a procedure for replacing filter media:

The required equipment is as follows:

The required equipment is as follows:

- (1) Nonsparking, conductive tools
- (2) Personal grounding equipment (wrist-strap, flexible cord)
- (3) Bonding cables and clamps
- (4) Personal protective equipment
 - (a) Flame-retardant coveralls
 - (b) Face shield
 - (c) Hard hat
 - (d) Safety glasses
 - (e) Static-dissipative safety boots
 - (f) Nuisance dust mask

The steps of the procedure are as follows:

- (1) Notify system operators that the affected dust collection systems will be shut down and locked out in accordance with the company lockout/tagout procedure.
- (2) Shut down all processes providing powder to the collector (e.g., atomization, classification).
- (3) Isolate the collector by means of valves or blank-off plates in ductwork.
- (4) Disable and lock out pulsing system associated with the collector.
- (5) If a forklift and cage is required for access to the collector, ensure that the forklift and cage are bonded to the collector frame by bonding cables and clamps.
- (6) Ensure that all personnel engaged in the change procedure are bonded to the collector by personal wrist straps and bonding cables at all times during the procedure.
- (7) Open the collector access door/port using nonsparking tools.
- (8) Remove the cartridges/bags, taking care to minimize the generation of suspended dust.
- (9) Ensure that cartridges/bags that have been removed are handled in accordance with established cleaning and disposal procedures.
- (10) Install the new cartridges/bags.
- (11) Perform and document a continuity check.
- (12) Reinstall the access door/port.
- (13) Thoroughly clean the equipment and surrounding area of any residual powder/dust generated as a result of the procedure in accordance with company housekeeping procedures.
- (14) Open the valves leading to/from the collector, or remove any blank-off plates previously installed.
- (15) Purge the collector, if required, and contact QC for purge sign off.
- (16) Remove all locks/tags previously installed and re-energize the pulse system.
- (17) Notify system operators that the procedure is complete and the affected system is operational.

Collectors should be provided with barriers or other means of protection of personnel.

A.22.9.4.4.2.10(A) During normal use of cartridge filters, the V portion of the pleats will pack with material that cannot be dislodged during actions such as filter cleaning. This accumulation will allow pyrophoric metal dusts to ignite, creating a high risk for a deflagration.

A.22.9.4.4.2.11(C) Historical incidents have shown that providing explosion suppression, isolation, and venting might be more difficult with certain combustible metal dusts than it is for other types of combustible dusts. Caution must, therefore, be used when applying NFPA 68 and NFPA 69 to metal dusts. It is also important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide evidence that the explosion protection is effective for the specific combustible metal. See 22.9.8.2.

A.22.9.4.4.2.11(C)(1) Deflagration venting is important for combustible metal dust due to the high maximum explosion pressures reached and the extremely high rate of pressure rise. Where deflagration venting is used, its design should be based on information contained in NFPA 68. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. Dust collectors, when provided by a manufacturer for other applications, seldom have properly sized venting to handle a combustible metal dust explosion.

A.22.9.4.4.2.11(C)(1)(b) Most combustible metals will react with water (i.e., the oxygen in water can oxidize the metal and generate hydrogen). In most cases, deflagration vent ducts designed for metal dust deflagration would be inadequate to vent a hydrogen explosion or a hybrid hydrogen and combustible metal dust explosion. Vent ducts could be pitched downward to allow moisture to drain from the vent duct, or vent duct covers could be used to prevent water from entering the vent duct.

A.22.9.4.4.2.11(C)(2) The maximum allowable concentration of oxygen is very dependent on the material, its chemical composition, and, in the case of particulate solids, the particle sizes. In addition, it is not advisable with many combustible metals to eliminate oxygen completely from the transport gas. During transport, particles can be abraded and broken, exposing unoxidized metal (virgin metal) to the transport gas. When that metal is finally exposed to oxygen-containing air, the rapid oxidation of the virgin metal could produce sufficient heat to ignite the material. It is therefore preferable to provide for a low concentration of oxygen in the transport gas stream to ensure the oxidation of virgin metal as it is exposed during the course of transport.

A.22.9.4.4.2.11(C)(4) Historically, effective deflagration suppression systems have not been commercially available for highly reactive combustible metals. With some metals and quantities of suppressant, the heat of the combustion of the metal can cause decomposition of the suppressant and produce higher overpressures than the metal alone. (See *"Flammability Limits of Dusts: Minimum Inerting Concentrations."*)

More recently, deflagration suppression systems have become commercially available for some combustible metal dusts. The user should ensure that the supplier of the deflagration suppression system is fully aware of the characteristics of

the combustible metal and that the suppression system has been shown to be effective with the specific material being handled in the system. Some suppression systems have only been shown to be effective for combustible metals with P_{max} below approximately 8 bar and K_{St} below approximately 150 bar-m/s.

A.22.9.4.4.2.11(C)(5) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling.

A.22.9.4.4.2.11(C)(6) For information on dust retention and flame-arresting devices, see Section 9.7 in NFPA 68. The effectiveness in this section is intended to mean that the device has been certified to be used with the material. Certain particulates can get stuck in the flame-venting device because of the physical shape of the metal particles. The certification should include the kinds of particles for which the flame-arresting device would not be effective. The manufacturer should demonstrate that the device is effective for the type of metal to be collected.

The justification should address potential pressurization of the surrounding building or enclosure as well as a minimum safe distance for personnel.

A.22.9.4.4.2.11(F) The purpose of this requirement is to protect dust collectors that have combustible metals present in the collector. Many dry-type dust collectors are used for collection of dust from grinding and similar operations in which the collected material is not combustible; in these cases, isolation is not required.

A.22.9.4.4.2.12(A) Some materials can represent significant hazards in small quantities, and care should be taken in determining the emptying frequencies for collection of these materials.

A.22.9.4.4.2.14 Indoor dry-type dust collectors for combustible metal dust should be used only where it is not feasible to use an indoor wet-type AMS or outdoor dry-type AMS. In most cases, an indoor dry-type AMS will create a greater hazard than other options. For instance, a fire in an indoor dry-type AMS can more readily spread to the building. A combustible metal fire in an indoor dry-type AMS can be extremely difficult, if not impossible, for emergency responders to control using normal firefighting techniques. Because of this increased hazard, indoor dry-type AMS are allowed only for combustible metals that meet certain thresholds for K_{St} , P_{max} , and minimum ignition energy, and the AMS requires a greater level of protection.

A.22.9.4.4.2.14(H) A break or leak in a filter can allow dust to pass through the fan, which would create a hazard. This often occurs with improper filter installation (whether bag or cartridge).

A.22.9.4.4.2.14(I) The purpose of this requirement is to reduce the potential for a duct fire fueled by combustible dust accumulation due to an upset condition in the system. Two examples of upset conditions leading to dust accumulation are a filter that has failed and emissions from newly installed filters due to a lack of film coating on the filter surface. It is recommended that design duct velocities be sufficient to keep the combustible dust in suspension even in an upset condition. Ducts with multiple elbows and that are longer than 16.4 ft (5 m) should be inspected periodically for dust accumulation.

This assumes the AMS fan exhaust duct will discharge outside and not inside (in accordance with the requirements in 22.9.4.4.6). Discharging the fan exhaust from an AMS outside to a safe location is always preferable, as filters can fail and allow the discharge of hazardous dust.

A.22.9.4.4.2.14(J) Accumulation of dust can occur in both the upstream and downstream ducts of collectors. Dust accumulations in the duct can allow an explosion to propagate through significant lengths of duct and rupture the duct.

A.22.9.4.4.2.14(K)(2) Historically, effective chemical isolation systems have not been commercially available for highly reactive combustible metals. More recently, chemical isolation systems have become commercially available for some combustible metal dusts. The user should ensure that the supplier of the chemical isolation system is fully aware of the characteristics of the combustible metal and that the isolation system has been shown to be effective with the specific material to be handled in the system.

The intent is to prevent a deflagration from propagating into the building by rupturing an exhaust duct located inside of the building.

A.22.9.4.4.2.14(L) It is recommended that indoor dry-type AMS for all combustible metals meet these requirements.

A.22.9.4.4.2.14(L)(2) Most combustible metals cannot be effectively extinguished with water because of the potential for steam explosions and the reaction with the metal (which generates hydrogen). Table A.22.9.9.3 should be consulted to determine if water is an effective extinguishing agent.

For metals not listed in Table A.22.9.9.3, testing should be performed with representative forms and quantities of the combustible metal to demonstrate that they can be effectively extinguished with water. This testing should be reviewed with the authority having jurisdiction and with the firefighters responsible for fighting fires at the facility.

A.22.9.4.4.2.14(M) An abnormally high pressure drop can indicate a significant buildup of material or blinding of the filters, which can create a hazard and decrease the flow rate and efficiency of the collection system. This is also a requirement for all dry-type filter media AMS.

A.22.9.4.4.2.14(O)(3) Some fire-extinguishing agents can cause an oxygen deficient atmosphere.

A.22.9.4.4.2.15 See Figure A.22.9.4.4.2.15.

A.22.9.4.4.2.15(D) The concern is that if a deflagration did occur in the portable dust collector, flames propagating from the collector could disperse and ignite fugitive dust accumulations in the area, causing a flash fire or explosion. The intent of portable dust collection is to prevent the accumulation of hazardous quantities of fugitive dust. Hazardous levels of dust should be cleaned prior to using the portable dust collector. Portable dust collectors that are rated for Class II areas are typically certified to not serve as ignition sources for existing hazards. However, the collection chamber in a dry collector can still be subject to a deflagration due to other ignition sources, including, but not limited to, hot embers, open flames, and sparks. A deflagration inside the dry collector can propagate outside of the collector or rupture the collector and ignite fugitive dust in the area.

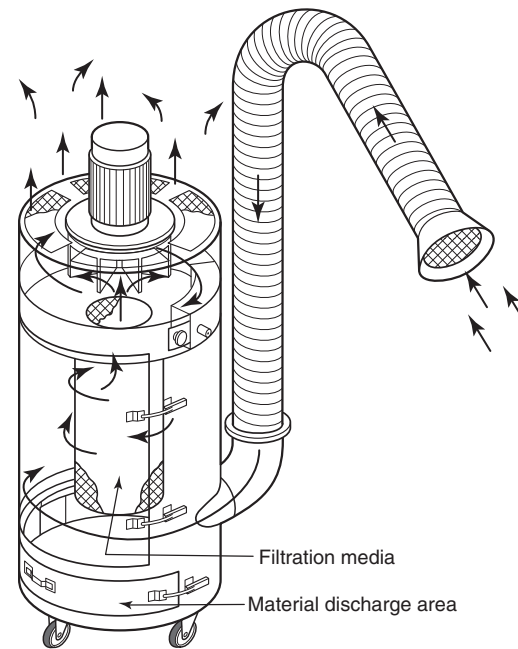


FIGURE A.22.9.4.4.2.15 An Example of a Portable Media-Type Dust Collector.

A.22.9.4.4.2.15(E) Small portable AMS also pose an explosion hazard, but NFPA 69 explosion protection might not be practicable. It is advisable to limit transient personnel around unprotected AMS.

A.22.9.4.4.2.15(L) It is recommended that each use without a new connection to ground is considered a single use.

A.22.9.4.4.2.15(N) The purpose is to limit the maximum amount of collected dusts to 5 lb (2.2 kg) at any time. It is good practice to empty this device daily, even if the 5 lb (2.2 kg) limit is not reached.

A.22.9.4.4.2.16(A) It might be necessary to isolate certain spark- or hot metal particle-producing operations to prevent them from becoming an ignition source for other operations.

Use of dry-type media AMS with any ember- or spark-producing equipment always requires mitigation of the situation. Otherwise, there is high risk of a fire or deflagration event in the AMS.

Spark arrester systems involve a range of technologies with final selections based on both the process conditions and the materials being processed.

Wet-type AMS promote quenching of hot particles that might serve as ignition sources, thereby substantially reducing the risk of a fire or deflagration event in the AMS.

A.22.9.4.4.2.16(B) Hot metallic nanoparticles can be present in welding fumes and dusts produced in additive manufacturing processes. When these processes involve reactive metals, the nanoparticulate dust can be pyrophoric.

A.22.9.4.4.2.16(C) Fires have been caused by the ignition of ordinary combustibles that entered these types of dust collection systems. In some cases, burning paper, labels, rags, ciga-

rettes, and other materials are able to propagate further through a dust collection system.

A.22.9.4.4.3 Figure A.22.9.4.4.3(a), Figure A.22.9.4.4.3(b), Figure A.22.9.4.4.3(c), and Figure A.22.9.4.4.3(d) show examples of liquid precipitation collectors.

A.22.9.4.4.3.5 No wet-type AMS is 100 percent efficient. Over time, the humid air wets the fine particles that pass through the AMS into the outlet and outlet ducting so that the particles agglomerate and tend to build up a combustible cake- or spongelike deposit (sludge) on the inner surface. If left uncleaned, this material can represent a significant deflagration risk.

A.22.9.4.4.3.6 The vendor providing the wet-type AMS should provide a warranty of performance based on the design conditions. The owner/operator should provide adequate maintenance and monitoring to ensure the AMS meets or exceeds those performance or “efficiency-of-dust-capture” requirements at all times during normal operation. Typically this involves maintaining the operational condition of the AMS and AMD

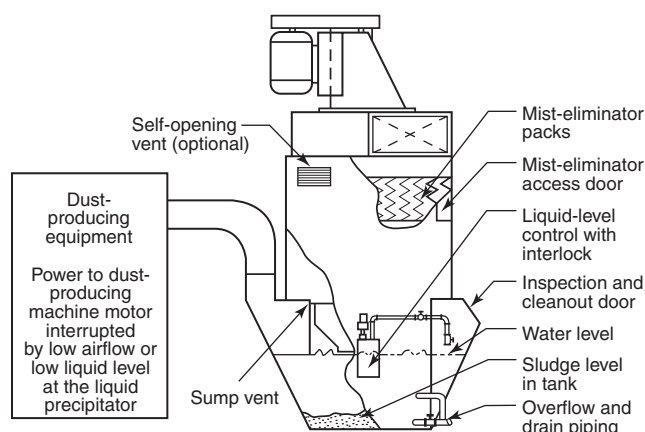


FIGURE A.22.9.4.4.3(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

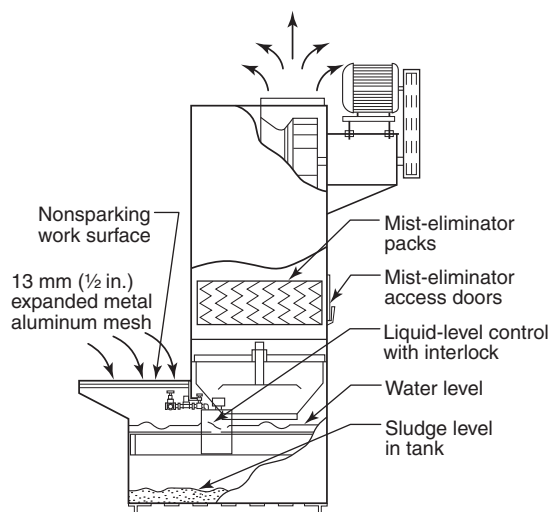


FIGURE A.22.9.4.4.3(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

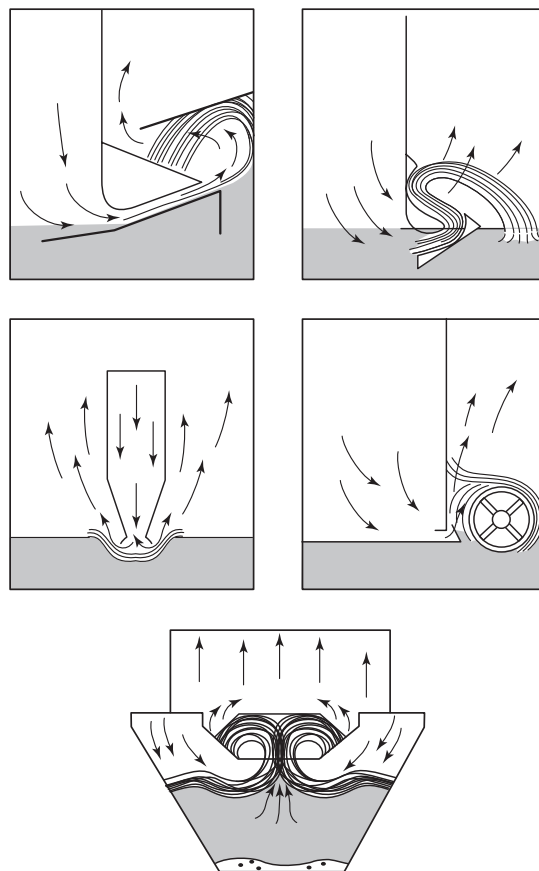


FIGURE A.22.9.4.4.3(c) Five Methods of Precipitating Dust in Precipitators.

(i.e., usually a fan package) and monitoring the performance of both.

A.22.9.4.4.3.8(A) Water level, water supply, or both in the operation of wet-type dust collectors is very important to the overall efficiency of the equipment. AMD (i.e., fan) performance is directly related to the amperage draw of the fan drive motor and can be used in conjunction with the water level or flow rate for system performance monitoring. Therefore, water level or flow rate control logic that shuts the machine down in an underfill, overfill, or lack of flow situation is necessary. Should a malfunction or unacceptable level of performance be detected, this would allow the control logic/system to shut down the vented equipment, the entire system, or both with necessary alarms to assure plant personnel are alerted.

A.22.9.4.4.3.9 Most wetted combustible metal dust that is not submerged under a cover of water is highly flammable and very dangerous. The reaction of most combustible metals with water produces hydrogen, which is highly flammable.

A.22.9.4.4.3.9(A) Containers preferably should not hold more than 50 lb (23 kg) each.

A.22.9.4.4.3.10 The reaction of most combustible metals with water produces hydrogen, which is highly flammable. Most wetted combustible metal dust that is not submerged under a cover of water is highly flammable and very dangerous. It should not be trapped in nonventilated areas of buildings,

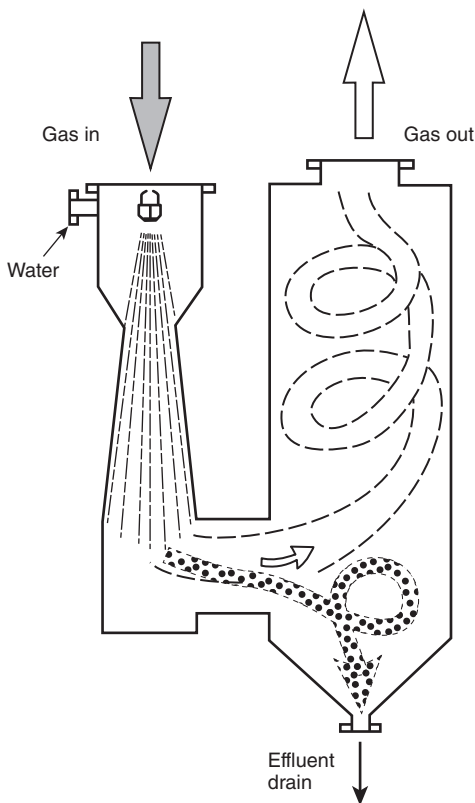


FIGURE A.22.9.4.4.3(d) Typical Venturi-Style Wet-Type AMS/Scrubber.

equipment, or enclosures. Exhaust vents should be located in areas free of potential ignition sources because of the possible production of hydrogen.

The vent should exhaust to a well-ventilated area where hydrogen gas can dissipate. The vent should not exhaust near inlets to air-handling systems or other equipment that would direct hydrogen gas into a building or other enclosure. See Table 10.3.2.1 of NFPA 55 for guidance on vent discharge location.

It should also be noted that hydrogen is lighter than air. Interactions between differing metal fines, such as magnesium and aluminum alloy (if the aluminum contains more than 0.5 percent to 1 percent copper) in wet collector sludge, can lead to hydrogen evolution and heat generation greatly exceeding that produced by magnesium fines alone. [See Figure A.22.9.4.4.3(a), Figure A.22.9.4.4.3(b), Figure A.22.9.4.4.3(c), and Figure A.22.9.4.4.3(d).]

A.22.9.4.4.6 Recommended design, maintenance, and operating guidelines for recirculation of industrial exhaust systems, as described in the ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice*, should be followed.

A.22.9.4.4.6.1(1) Adiabatic flame temperatures for some metals are contained in “Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds,” (Cashdollar and Zlochower, 2007). Metals with calculated adiabatic flame temperatures below 4172°F (2300°C) include iron, copper, nickel, zinc, and lead.

A.22.9.4.4.6.1(4) The system should be designed, maintained, and operated according to accepted engineering practice, and the AMS efficiency should be sufficient to prevent dust in the recycled air from causing hazardous accumulations of combustible dust in any area of the building. This objective could be evaluated based on design calculations or testing prior to operational acceptance.

A.22.9.4.4.6.1(5) 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, “Permit-Required Confined Spaces.”

A.22.9.4.4.6.2 Short, straight ducts minimize the likelihood of accumulations, reduce the energy requirements to maintain duct velocity, and help to mitigate deflagration hazards. Minimizing the turns reduces both the energy requirements and the likelihood of material accumulations.

A.22.9.4.4.6.3 Any moisture entering the system can react with most metal powders, generating heat and hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.22.9.4.4.6.4 Hoses and flex connections are often required for hood movement, venting of weigh hoppers, and physical limitations that make the use of metal ducting infeasible. However, the length of hoses or flex connections used should be the minimum required to achieve the desired results. Excessive lengths can result in additional turns, kinks, and other high-energy losses that lead to lower duct velocities, poor performance, and accumulations of combustible dusts.

A.22.9.4.4.6.5 The typical materials used in hose and flex connection construction tend to create electrostatic charges when air (with or without dust) passes through them. Unless these electrostatic charges are successfully bonded/grounded, the accumulated static charge can be released, resulting in a possible deflagration. Continuity of the bonding/grounding must be achieved by the construction of the hose/flex connection, the use of wire across the span where the hose/flex connection is used, or both. Most static dissipative or conductive hoses have grounding wires that can be used at each end. Use of conductive coatings is not recommended because they can wear off easily due to the abrasion of the dust conveyed.

Hoses normally require significantly more energy to allow air (and dust) flow compared to metal ducting. Typically, poor hose selection can result in 5 to 10 times the energy loss (per foot) compared to an equal diameter metal duct. The type of hose used, especially the interior construction, will greatly influence the energy required. Hoses with smooth interiors (versus convoluted) should be used.

A.22.9.4.13.1 Possible protection methods could include but not be limited to the following:

- (1) Zero speed switches
- (2) Flow indicators
- (3) Level probes
- (4) Heat sensors
- (5) Dust level sensors
- (6) Mechanical feeding devices equipped with a shear pin or overload detection device and alarm.
- (7) An alarm sounding at the operator control station.

- (8) Direct connection of drives used in conjunction with feeders, air locks, and other material feeding devices
- (9) 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
- (10) Mechanical feeding devices equipped with a shear pin or overload detection device and alarm
- (11) An overload detection alarm sounding at the operator control station

A.22.9.4.14 Examples of bucket elevators can be Z conveyors, open bucket elevators, enclosed bucket elevators, and angled bucket elevators.

A.22.9.4.14.2 Access doors should be dusttight. Pits should be lighted and accessible and should provide ample room for cleaning, lubrication, repairs, and replacement of parts. Elevator boot sections and the spouts feeding them should be constructed so as to minimize choking of the boot.

A.22.9.4.14.4 Any motor or combination of motors utilized should be no larger than the smallest standard motor(s) capable of meeting this requirement.

A.22.9.4.14.5 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.

A.22.9.4.14.10 See A.21.9.4.15.5.

A.22.9.4.14.12 Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether monitoring is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation.

A.22.9.4.15.1 Examples of enclosed conveyors are enclosed belt conveyors, screw conveyors, drag conveyors, flexible screw conveyors, “sandwich” conveyors, tubular mechanical conveyor devices, etc.

The range of mitigation methods can include deflagration protection, monitoring, diversion, dust collection, dust suppression, etc.

Throwing of material for a considerable distance (i.e., not confined in spouts) should not be permitted unless absolutely necessary in open or semi-confined spaces, such as in barge and ship loading or in large bulk storage areas.

When using enclosed conveying equipment, an evaluation should be conducted to determine if ignition sources might be present and contained by the proposed enclosure. Dust collection should be considered with proper design to assure constant airflow and collection of the dust generated inside the enclosed area or device.

A.22.9.4.15.2 Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature, flow, no flow indicators, motion detectors, and similar devices.

A.22.9.4.15.2.1 The purpose is to control the feed to the material conveyor to prevent additional hazards.

A.22.9.4.15.4.1 Belts shall be fire resistant by complying with the requirements of the Mine Safety and Health Administration (MSHA) 2G flame test for conveyor belting in 30 CFR 18, Section 12.18.65, or the flame test for belting in Part 13.2 of

ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type*.

A.22.9.4.15.5 For equipment lined with combustible material (other than spouts), a means should be provided to have access for firefighting. The use of noncombustible ceramic or steel linings is preferred. If combustible linings are used extensively, it is suggested that a firebreak of noncombustible lining material be used at a grain stream direction change point.

A.22.9.4.15.6 Not all enclosed conveyors require explosion protection. This can be evaluated based on a risk assessment. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure.

A.22.9.4.16.2 Typical methods include magnets, screens, or other methods of detection or classification and that could occur in upstream processes.

A.22.9.4.16.5 The following information from FM Property Loss Prevention Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire*, Chapter 2.3.4.6, and CCPS *Guidelines for Safe Handling of Powders and Bulk Solids*, Chapter 5.3.2, Blenders and Mixers, will be helpful when conducting a DHA.

It is recommended that all characteristics of metal dusts and powders are considered in the design and type of the mixer/blender. Examples are self-heating, reactivity, incompatibility, abrasion, etc.

A.22.9.6.1 It is not always possible or practical for existing facilities to be in compliance with new provisions of a standard on the effective date of that standard. Therefore, retroactivity in this section means that a plan to achieve compliance within a reasonable time frame should be established.

A.22.9.6.5 Housekeeping can reduce or eliminate the electrical area classification for a location where combustible metal dust is present. Electrical equipment upgrades to meet Article 500 of *NFPA 70* can be costly and users might better focus on preventing fugitive dust from escaping equipment and accumulations to minimize the extent of the hazardous (classified) areas.

Finding combustible metal dust or powder within electrical equipment and components should warrant more frequent inspection and cleaning.

A.22.9.6.6.2.1 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 m³.

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 0.075 mm (200 mesh).

A.22.9.6.6.2.1(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.22.9.6.6.2.1(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.22.9.6.6.2.2 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.22.9.6.6.2.2(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.22.9.6.6.2.2(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.22.9.6.6.2.3 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.22.9.6.6.3.1 A hybrid mixture can be present when handling metals in a combustible form either due to generation of hydrogen through the reaction of moisture or by intentional presence of solvents during milling operations. Even when the metal has an MIE of greater than 30 mJ, the hybrid mixture MIE can be less than 30 mJ.

A.22.9.6.6.6.1 A hybrid mixture can be present when handling metals in a combustible form either due to generation of hydrogen through the reaction of moisture or by intentional presence of solvents during milling operations. Even when the metal has an MIE of greater than 30 mJ, the hybrid mixture MIE can be less than 30 mJ. The concern is for impact sparks as well as electrostatic discharge.

A.22.9.6.6.6.2 Under certain circumstances, such as impacts with rusted iron or steel, aluminum cannot safely be considered to be nonsparking, since a minor thermite reaction can be initiated. For details, refer to Eisner, "Aluminum and the Gas Ignition Risk," and Gibson et al., "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction."

Bonded and grounding of hand tools most often occurs through the person handling the tools. The use of insulating gloves or shoes could interrupt this grounding and bonding path.

A.22.9.6.6.7 Under certain circumstances, such as impacts with rusted iron or steel, aluminum cannot safely be considered to be nonsparking, since a minor thermite reaction can be initiated. For details, refer to Eisner, "Aluminum and the Gas Ignition Risk," and Gibson et al., "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction."

A.22.9.6.6.7.1 In complex installations of machinery and equipment, the danger of the occurrence of an isolated conductor is possible. Therefore, it is highly recommended that bonding as well as grounding of permanently installed equipment be practiced. Redundant grounding and bonding provide a means of further eliminating this potential danger. NFPA 77 provides guidance on how to ground and bond equipment.

A.22.9.6.6.7.1(B) Examples are gaskets between ductwork sections, and flexible hoses.

A.22.9.6.6.7.2 Portable processing equipment should be constructed in such a fashion that grounding can be readily accomplished. For instance, metal carts should have static-dissipative wheels. Even with static-dissipative wheels, it is good practice to ground portable processing equipment with an external ground wire. Dirt and other material can coat the wheels, which could isolate the cart from the ground provided from static-dissipative floors. Additional attention should be given to bonding of portable equipment to eliminate the dangers of isolated conductors. Special attention should also be given to painted or coated equipment to ensure that the bonding connection provides continuity.

A.22.9.6.6.7.3 It is recommended that a periodic test program be instituted to monitor the level of resistance to earth ground as well as to ensure that the integrity of fixed grounds remains acceptable. The need to ensure that grounding criteria are satisfied becomes more urgent as finer particle-sized material is processed. As always, it is recommended that a hazards analysis be conducted to ensure that bonding and grounding protocols match the sensitivity of the actual powders being processed.

A.22.9.6.15.2 Information on spark-resistant fans and blowers can be found in AMCA 99, *Standards Handbook*.

A.22.9.6.15.4 Fans or blowers can also be provided with vibration indicating devices, arranged to sound an alarm, to provide shutdown, or both, in the event of blade or rotor imbalance, or bearing or drive problems.

A.22.9.6.16 Special precautions are necessary to prevent ignitions during dressing of the wheels used for grinding combustible metal castings. Hot metal thrown off by the dressing tool can ignite dust or deposits in the hood or duct.

A.22.9.8.2 Representative metal dust should have not only a similar K_{st} , but also a similar maximum adiabatic flame temperature to the dust that will be handled in the process. The test vessel should be selected to closely approximate the volume and geometry of the protected enclosure.

A.22.9.9.3 Table A.22.9.9.3 provides information on recommended extinguishing agents.

Experience has shown that sodium chloride is one of the most effective chemicals for containing fires involving combustible-metal powder. Firefighting salts should be checked on a regular basis (such as weekly or monthly) to ensure that they have not absorbed moisture (usually evidenced by caking).

If damp salt is applied to a combustible-metal fire, the intense heat will flash the moisture to steam in an explosive manner.

Various commercial fire extinguishers are available with agents approved for combustible-metal fires. When using any approved agent, it is important to completely cover the burning material, thus reducing the oxygen supply and slowing the burn rate until the fire is extinguished. If the agent is removed from the burning material too early, re-ignition can occur.

A.22.9.9.3.1 Dry sodium chloride or other dry chemical compounds suitable for extinguishing or containing combustible-metal fires can be used as substitutes for Class D fire extinguishers.

Class B extinguishing agents will usually greatly accelerate combustible-metal fires and can cause the burning metal to explode.

A.22.9.9.3.5(5) Nitrogen can be considered as an extinguishing agent for iron, steel, and many alkali metals. Gaseous nitro-

gen is not a suitable extinguishing agent for lithium. Some nitrogen–argon blends have been shown to be an effective extinguishing agent for some combustible metals.

A.22.9.9.3.9 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.22.9.9.3.9.2(A) Milling of aluminum with ignitable solvents is practiced in the manufacture of aluminum flake used in pigments and powders. The material is handled as a slurry during processing. Some of the product is marketed as a paste; other portions are filtered, dried, sometimes polished, and sold as dry flake powder. The solvents employed are generally moderately high-flash-point naphthas. A fire in an aluminum powder slurry is primarily a solvent fire and can be fought using Class B extinguishing agents, except for halogenated extinguishing agents.

Major producers usually employ fixed extinguishing systems of carbon dioxide or foam in this area. Some Class B portable

Table A.22.9.9.3 Combustible Metal Fire-Extinguishing Agents Quick Reference Chart

Extinguishing Agents	Metals								
	Alkali Metals (Calcium, NaK, Sodium)	Lithium	Aluminum	Iron and Steel	Magnesium	Niobium	Tantalum	Titanium	Zirconium
Graphite ^a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Met-L-X	Yes ^b	No	Yes ^b	Yes	Yes ^b	Yes ^b	Yes ^b	Yes ^b	Yes ^b
Lith-X	Yes ^b	Yes ^b	No	No	No	No	No	No	No
Copper powder	Yes ^b	Yes ^b	Yes	No	No	No	No	No	No
Dry flux	Yes	Yes	Yes ^b	No	Yes ^b	No	No	No	No
Dry sand	Yes	Yes	Yes ^b	Yes	Yes ^b	Yes ^b	Yes ^b	Yes ^b	Yes ^b
Dry lithium chloride	Yes	Yes	No	No	No	No	No	Yes	Yes
Dry soda ash	Yes	Yes	Yes	No	Yes	No	No	Yes	Yes
Dry sodium chloride	Yes	Yes	Yes ^b	No	Yes ^b	Yes ^b	Yes ^b	Yes ^b	Yes ^b
Water	No	No	No	Yes	No	No	No	No	No
Foam	No	No	No ^c	Yes	No	No	No	No	No
Argon	Yes ^b	Yes	Yes ^b	Yes	Yes ^b	Yes ^b	Yes ^b	Yes ^b	Yes ^b
CO ₂	No	No	No	No	No	No	No	No	No
Nitrogen	Yes ^b	No	No	Yes	No	No	No	No	No
Halon	No	No	No	No	No	No	No	No	No
Hydrocarbon Clean Agent	No	No	No	No	No	No	No	No	No

Note: When combustible metals are blended with other materials, the extinguishing agent should be compatible with the combustible metal.

^aGraphite includes powders, expanded graphite, and carbon microspheres (coke).

^bPreferred extinguishing agent.

^cAqueous film forming foam (AFFF) has been shown to be effective on aluminum paste fires in the incipient stage where a Class B solvent is the primary fuel.

extinguishers also are provided. Obviously, judgment should be used in determining whether Class B extinguishing agents can be used safely. If the extinguishing agent is carefully applied, it will be evident if it accelerates the fire. If the agent does accelerate the fire, its use should be discontinued, and a dry, inert granular material should be used. A fire in filter cake, a solvent-wetted but semi-dry material containing aluminum, can be a solvent fire or it can, at some point, exhibit the characteristics of a powder fire, at which time it should be treated as such. If the aluminum metal has ignited, it can continue to burn under a crust without flames.

A.22.9.9.3.9.2(B) Re-ignition can occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

A.22.9.9.3.10.1 The use of fine, dry sand, preferably less than 20 mesh, or other approved powder is an effective method of isolating incipient fires in combustible-metal dust. An ample supply of such material should be kept in covered bins or receptacles located in the operating areas where it can be reached at all times. A long-handled shovel of spark-resistant metal should be provided at each such receptacle to afford a ready means of laying the material around the perimeter of the fire.

Nearly all vaporizing liquid–fire-extinguishing agents react violently with burning combustible metal, usually serving to greatly intensify the fire and sometimes resulting in explosion.

Water hose streams should not be used. The impact of the water stream can lift enough dust into the air to produce a strong dust explosion. In addition, water reacting with aluminum can give off highly flammable hydrogen gas.

A.22.9.9.3.10.3 Application of wet extinguishing agents accelerates a combustible metal fire and could result in an explosion.

The application of pressurized extinguishing agents should be performed only by trained personnel because of the danger of spreading the burning powder or chips or creating a dust cloud.

Bulk dry extinguishing agents should be provided in areas where chips and powders are produced or used and should be kept dry (i.e., free of moisture).

A.22.9.9.5.1.1 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 most burning combustible metals, hydrogen gas can be generated. When confined in an enclosed space, dangerous levels of hydrogen gas can collect and result in the potential for a hydrogen explosion. The metal will likely spread and spew burning material.

A.22.9.9.5.1.2 Iron and steel are examples of combustible metals where sprinkler protection could be considered. Automatic sprinkler protection is not recommended for buildings that contain blending and melting operations.

A.22.9.9.5.1.6 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section metal and produce a well-involved metal fire before automatic sprinklers operate. Special importance, therefore, should be attached to prompt fire detection and alarm service, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13.

A.22.9.9.5.2.1 The reaction of alkali metals, especially burning alkali metals, with water is extremely hazardous. Where combustible loading in areas used for alkali metals processing is determined by the authority having jurisdiction to require sprinkler protection, consideration should be given to the installation of preaction sprinkler systems to reduce the opportunity for accidental discharge.

Where the presence of non-water-reactive, combustible materials has been determined to require sprinkler protection, the quantities of alkali metals exposed to sprinkler action and the ability of workers to quickly secure the exposed alkali metals (e.g., place the lid back on the drum to reseal the container) also need to be evaluated.

A.22.9.9.5.2.6 See NFPA 499.

A.22.10.2 The objectives in fighting combustible metal fires are isolation and containment, rather than extinguishment. Water and other liquids have proved ineffective in extinguishing combustible metal fires. Streams of water intensify most combustible metal fires by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of combustible metal are involved. The great affinity of high-temperature combustible metal for oxygen frees a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot combustible metal can result in a steam explosion.

Because of their unique nature, combustible metal fires demand a comprehensive fire protection plan wherever combustible metal is processed, handled, used, or stored. This plan should include specific actions in the event of a combustible metal fire and should be coordinated with the local facility management, responding firefighters, and medical personnel.

The plan should recognize the extreme hazards associated with combustible metal–water reactions that might occur with sprinkler water. Specific attention should be given to an evacuation plan for personnel in the event of any release of water.

Properly trained personnel who work with combustible metal know its hazards. Such personnel are best equipped to extinguish a combustible metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

A.22.10.2.2 Employee health and safety in operations depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

A.22.10.2.2.2 Fire blankets have been found to be effective for extinguishing clothing fires. They should be distributed in plant areas where water is excluded.

A.22.10.2.5(1) The physical state of the product, such as chips, powder, fines, and dust, and the quantity of product involved in the fire, potentially involved in the fire, or both, are extremely important factors for emergency responders.

A.22.10.2.5(13) Fires involving large quantities of product within structures can result in rapid heat buildup and smoke generation beyond that normally encountered in fires involving ordinary combustibles.

A.22.10.4.2 Molten metal and molten metal chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, if contacted with water or residual moisture.

A.22.10.5.1 Where employees are expected to conduct any type of firefighting operations, the employees should receive training on a regular basis. Additional eye protection should be considered for personnel expected to fight a fire to protect against the higher degree of emitted light from the burning combustible metals.

Properly trained personnel who work with specific combustible metals know their hazards. Such personnel are best equipped to extinguish metal fires in their incipient stage. Training should include sufficient information to determine if extinguishment can be accomplished safely and effectively.

A.22.10.5.8.1 Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

A.22.10.5.9.1 One of the greatest dangers to firefighters is the splattering effect of burning alkali metals. Molten alkali metal is very fluid and easily spread; therefore, extreme care needs to be taken when applying firefighting agent. The force used to deliver agent from an extinguisher can cause the molten alkali to splash to adjacent areas. Therefore, the delivery technique is very important. If direct agent application becomes hazardous, indirect application techniques should be used. Deflecting agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

A.22.10.5.9.2 Forming a crust over burning alkali metals reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since alkali metal tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If the alkali metal surfaces, additional agent should be applied to strengthen the crust.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the alkali metals. In the case of copper powder, an alkali metal-copper alloy is formed as heat is absorbed from an alkali metal. Once the crust is formed, the temperature of the alkali metal decreases and exothermic reactions are reduced. Extreme care should be taken to ensure that the crust is not disturbed or broken until the temperature of the alkali metal is decreased to the point where resolidification occurs (or in the case of NaK, until the mass is at or near room temperature).

A.22.10.6.2.2 It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper methods of fighting Class D fires. Professional or volunteer firefighters from outside the plant cannot be expected to be trained for the specific fire and life hazards associated with metal powder and fires. In the interest of their own safety, they should be directed by the plant's safety officer or firefighting officer.

A.22.14.2 Nanometal powder provisions in Section 22.14 and the rest of this chapter are limited to fire, flash fire, and explosion protection considerations. Nanometal powder toxicity

considerations, applicable to both combustible and noncombustible nanometals, are outside the scope of this document.

A.22.14.2.2 A mixture of 99 percent by weight micron-scale iron powder with 1 percent of 35 nanometer titanium powder has been ignited by electrostatic charge generation in a plastic hose. (See Wu, 2014.)

A.22.14.2.4 Any powder or dust collection methods used should be included as part of the DHA. Nanoparticles and ultrafine particles often have lower MIE, are prone to pyrophoricity, and are more reactive than similar larger particles. This increases the risk of ignition and limits the choice of suitable materials for the filtration media. Typical dry and wet dust collection systems are not effective on nanoparticles and ultrafine particles.

A.22.14.3.1.1 Equipment used and energy generated during exploding wire production of nanometals are described and quantified in the following publications:

- (1) Lerner, M., Vorozhtsov, A., Guseinov, Sh., and Storozhenko, P., "Chapter 4: Metal Nanopowders Production," *Metal Nanopowders: Production, Characterization, and Energetic Application*
- (2) Nazarenko, O., et al., "Chapter 3: Electroexplosive Nanometals," *Metal Nanopowders: Production, Characterization, and Energetic Application*

A.22.14.3.1.2 Guidance for blast wave protection can be found in the Center for Chemical Process Safety's *Guidelines for Consequence Analysis of Chemical Releases* and in the chapter on explosion hazards in NFPA's *Fire Protection Handbook*.

A.22.14.3.2.1 Figure A.22.14.3.2.1 is a process flow block diagram for nanometal production via plasma exposure heating and subsequent recondensation. Plasma temperatures required for commercial nanometal production of most metals are about 6000 K for an immersion period of 0.5 to 1 ms, and about 5000 K for longer exposure periods.

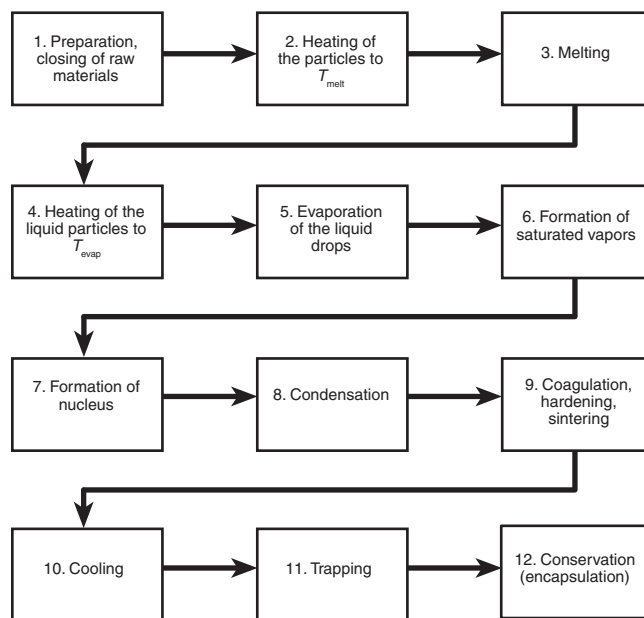


FIGURE A.22.14.3.2.1 Essential Stages of Plasma-Chemical Process to Produce Disperse NP by Recondensation.

A.22.14.3.3.1 Chemical process hazard evaluation methods and associated engineering process design methods are described in *Guidelines for Hazard Evaluation Procedures* and *Guidelines for Engineering Design for Process Safety*.

Reactants with special flammability, reactivity, and stability properties include sodium borohydride and hydrogel matrices containing iron, cobalt, nickel, copper, silver, and ruthenium. (See Sahiner, 2013.)

A.22.14.3.3.3 Examples of ignitable (flammable and combustible) liquid reactants and solvents used for nanometal synthesis are dimethylformamide for silver nanoparticles, toluene used in gold nanoparticle production, and ethanol for synthesis of nanoparticles of palladium, platinum, gold, and rhodium. (See Liz-Marzan, 2004.)

A.22.14.3.4.1 Biosynthesized metallic nanoparticles have advantages of reduced environmental impact, biochemical stability, and biocompatibility that render them attractive for antimicrobial applications; imaging applications; catalytic applications, such as reduction of environmental contaminants; and electrochemical applications, including sensing. (See Schrofel, 2014.)

Bioprocess safety guidelines are available in *Guidelines for Process Safety in Bioprocess Manufacturing Facilities*.

A.22.14.3.5 Metallic nanostructured coatings of various materials, including, but not limited to, paperboard, aluminum foil, and other metals, can now be produced by thermal spray pyrolysis processes. One example of this is described in the paper by Mäkelä, et al., “Nanoparticle Deposition from Liquid Flame Spray onto moving Roll-to-Roll Paperboard Material.”

A.22.14.4.1 Nanograde aluminum and titanium have been shown to auto-ignite during conveying in ducts with elbows. (See Wu, 2010.) LOC values for these and other nanometals can be lower than the LOC values currently in Table Y.3(b) and in NFPA 69, which are based on micrometer-sized dust samples. (See Mittal, 2013.)

A.22.14.4.4 Although explosibility tests with several nanometals have resulted in P_{max} values similar to those obtained with samples of larger particulate of the same material (see Krietsch, 2015), tests with other nanomaterials such as magnesium have produced the highest P_{max} values with nanometals of about 400 nanometer diameter (see Mittal, 2014). Some of the testing with successful measurements of P_{max} for nanomaterials required special sample injection methods to avoid preignition during sample transport into the test chamber.

A.22.14.5.1 For example, the physical size of nanoparticles present unique problems for typical AMS devices. Where significant quantities of nanoparticles are present, the device used to separate these particles from the conveying air or gas should provide separation efficiencies which meet the hazard mitigation requirements.

A.22.15.2 The committee is not currently aware of a listing standard specific to powder-based additive manufacturing machines. Many additive manufacturing machines are provided with CE declarations of conformance and might not be independently tested by third-party laboratories. The *International Fire Code* and Section 46.3 of NFPA 1 both require industrial additive manufacturing printers to be listed and labeled in accordance with UL 2011, *Outline of Investigation for Machinery*, or to be approved for the application based on a field evalua-

tion conducted by an approved agency. UL 2011 is not an additive manufacturing-specific standard. Some localities permit a listing through a third-party field evaluation.

A.22.15.2.1 A DHA for additive manufacturing and auxiliary equipment using powders requires a comprehensive understanding of this complex equipment, the process, and the powder used. A manufacturer's literature addressing the hazards of using this equipment is necessary but should not be used solely as input for the DHA. Selection of protective measures should be based on the combustibility properties of the particular alloys being used. The DHA should evaluate the need for inerting, proper PPE, and other fire and explosion protection measures during all the operations delineated in 22.15.3.

Additional hazards that should be considered are the use of dust collection, portable or centralized vacuum cleaning systems, pneumatic powder transfer systems, the handling of materials by personnel, manual transfer of materials, material storage, and so forth.

A.22.15.2.2 The knowledge and experience required to perform an additive manufacturing DHA is extremely specialized and requires distinct qualifications beyond those for performing DHAs involving metal or other types of combustible dusts. This specialized expertise is usually gained through performing the work of assessing and mitigating the unique combustible dust scenarios and hazard mitigation systems (e.g., inert gas, dilution/passivation) inherently designed into the various types of 3D printers, depowdering systems, powder conveying systems, and other complex additive manufacturing equipment.

A.22.15.2.4 See NFPA 79 for further information on emergency shutdown. The 50 lb (22.7 kg) threshold was established by the technical committee based on the higher hazard posed by handling large quantities of material.

A.22.15.2.4.2 The local manual shutdown should be near the control station for the machine. The remote manual shutdown should be located as follows:

- (1) It should be a minimum of 25 ft (7.6 m) away from the machine if located in the same room
- (2) It should be outside the equipment room if the room is too small for it to be located 25 ft (7.6 m) away from the machine
- (3) It should be in the path of the means of egress for the area

A.22.15.2.5.1 See NFPA 77 for information on conductive and static-dissipative liners and containers. If powder is received in containers that are not metallic or static dissipative, extreme care should be used in the transfer of powder from the container. The amount of free fall of the powder should be minimized. The rate of transfer should be slow to reduce the amount of static charges produced by the transfer. Although the shipping container cannot be grounded/bonded, consideration should be given to embedding a metallic grounding stick into the shipping container that would be in contact with the powder. NFPA 77 and A.9.6.6 of this standard provide extensive information on electrostatic discharges. Most electrostatic discharges will not exceed 100 mJ.

A.22.15.3.1.2 Based on information found in *Avoiding Static Ignition Hazards in Chemical Operations*, by Laurence G. Britton, 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 micron 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 micron 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.22.15.3.1.3 The formation of dust clouds can be minimized by reducing the free fall of the powder during transfer and controlling the flow rate of the transferring operation. Slower flow rates and shorter distance of free fall reduce the potential for dust cloud formation and static discharge. If the transfer container is not metallic, a bonding rod can be inserted in the transfer container that remains in contact with the powder while being transferred.

A.22.15.3.1.4 NFPA 499 provides diagrams for the extent of hazardous (classified) locations and permits the operator to establish a location as unclassified based on housekeeping or other dust mitigation actions. Manual removal of parts can generate dust clouds and should be considered in the equipment design.

A.22.15.3.2 There are large and small additive manufacturing (AM) printing production facilities ranging from many printers processing different powders in one or more large rooms to a single printer processing one metal. Similarly, there can be a range in the quantity of metal powders in storage, staging, use, and recovery. Given the wide variety of AM powder metals and alloys — including recovered and waste powder — and the range of ignition propensity and combustibility, DHAs are site-specific and should include an evaluation of the hazards of metal powders in storage and use. Some powders might have MAQs because they fall under flammable solids or other hazardous materials classification and, therefore, other requirements might exist.

A.22.15.3.2.2(1) Although the *International Building Code (IBC)*, *International Fire Code (IFC)*, or the NFPA combustible dust standards do not discuss how to determine water reactivity, UN Test N.5 (Division 4.3) described in the *Recommendations for the Transport of Dangerous Goods: Model Regulations — Manual of Tests and Criteria* is often used to determine the water reactivity of various combustible metal dusts or powders. Rather than determining the effectiveness of water in extinguishing or suppressing combustible metal dust fires, this test method is often used to determine the water reactivity of combustible metal dust or powders. However, there are several potential issues with this test method and its application. First, this test method is designed for transportation of materials that are classified as “Dangerous When Wet” and is frequently used to determine shipping and placarding requirements for Department of Transportation (DOT) regulations. This test method and the DOT regulations it is designed to meet are not applicable to industrial facilities where combustible metal dusts/powders are handled, generated, conveyed, and/or stored. The procedures outlined in this test method are also not designed to simulate the temperatures, relative humidity, powder wetting, internal equipment volumes, and other factors associ-

ated with various industrial metal-working equipment and processes. The ambient temperature, overall volume of glassware, nature of aqueous media, sample mass, and sample-to-liquid mass ratio are not fixed within any defined range in the UN N.5 test procedure. The variation in the UN N.5 testing protocols also does not allow for the establishment of a standardized testing error rate. Finally, the UN Test N.5 leaves much of the process of collecting and quantifying the flammable gas emissions up to each laboratory, which could significantly affect the accuracy of the reported gas evolution rate and lead to false positive errors.

Safety data sheets (SDSs) also often incorrectly indicate that the aluminum and titanium alloy powders processed in the 3D printers and other AM equipment are water-reactive materials and/or flammable solids. While the DHA could require additional testing to determine these classifications, historical testing data from several powder manufacturers infers that commonly used aluminum and titanium alloy powders do not meet the criteria for water-reactive materials or flammable solids. Due to these potential inaccuracies, SDSs alone should not be used as the sole source to determine the fire, deflagration, explosion, and/or reactivity hazards associated with any AM combustible metal dust or powder. This determination should instead be made by qualified individuals with documented expertise in assessing and mitigating the flash fire and explosion hazards associated with the affected AM equipment and processes.

A.22.15.3.3.1 See 7.4.1.3 and 10.1.1 in NFPA 77.

A.22.15.3.3.2 Bonding methods are described in NFPA 77.

A.22.15.3.4.2 Bonding methods are described in NFPA 77.

A.22.15.3.5 Powder transfer equipment includes any device used to move or convey powder from one portion of the system to the other.

A.22.15.3.6.1.1 Nitrogen can be considered a purge gas/extinguishing agent for iron, steel, and some alkali metals. Gaseous nitrogen is not a suitable extinguishing agent for lithium, titanium, tantalum, zirconium, niobium, hafnium, and magnesium. Some nitrogen-argon blends have been shown to be effective extinguishing agents for some combustible metals.

A.22.15.3.6.1.4 Oxygen or pressure sensor setpoints, sensor lag times, purge times, and other inerting parameters should not be changed without first analyzing and documenting the consequences to the inert gas system through the management of change (MOC) review process.

A.22.15.3.6.1.5 Although each oxygen sensor is calibrated by the sensor manufacturer prior to shipment and installation, this calibration fades over time and causes the sensor accuracy to diverge from its factory calibration settings. To limit the effects of “calibration drifting,” each sensor must be routinely exposed to a known concentration of test or span gas to verify accurate sensor response. Additionally, new oxygen sensors require calibration at the time of installation and until the calibration records demonstrate sensor stability.

Some sensor manufacturers indicate that oxygen sensors have an indefinite service life in “perfect” atmospheric conditions. However, oxygen sensors on 3D printers, filter modules, vacuum conveyors, sieving chambers, depowdering units, and other inerted AM equipment are constantly exposed to argon or nitrogen gas and extremely fine particulate and nanometal

condensate that have a documented history of poisoning and decreasing sensor accuracies. To prevent failures that lead to inaccurate readings, all these oxygen sensors should be calibrated once every 6 months and replaced at least every 12 to 18 months. The effectiveness of these and other calibration and replacement frequencies should also be analyzed during the DHA.

A.22.15.3.6.1.6 The introduction of noncompatible materials has the potential to result in an uncontrolled exothermic reaction. Only metal alloys known to be compatible with one another should be introduced without a thorough cleaning of the machine.

A.22.15.3.6.2.6 Operators should be trained in the effective methods of moving the loose powder and accumulations to the inerted dust collection while the printer remains inert. Loose powder accumulations in the print chamber are often required to be removed during the build process to ensure a quality product is produced. It is also required to prevent loose powder and dust accumulations within the printer to avoid the fugitive release of powder or dust when the build chamber is opened, as this can represent a flash fire risk. Dust collectors used for this purpose are often integrated into the print bed and must be inerted, or an alternative method acceptable to the authority having jurisdiction should be selected.

A.22.15.3.6.3 Powder spray printing includes powder printers that employ cold spray technology.

A.22.15.3.6.4 AM printing operations that are not clearly powder spray or powder bed, or those that might involve additional additives, including hydrocarbon-based resins and flammable solvents, can create additional hazards. The controls for these hazards have not yet been established.

A.22.15.3.6.5.1 Some printed parts trap loose powder within internal cavities. The part can be gently rotated prior to its removal to allow loose powder to be extracted. The part should be held in a position that minimizes the free-fall distance from the part to the floor of the print chamber.

A.22.15.3.6.5.2 Except when integrated into the equipment, compressed air is rarely used to remove the excess and residual dust or powder layers from the printed parts or interior/exterior equipment surfaces. However, compressed air cans are often used by printer operators to remove dust/powder layers from the laser window and some 3D printer process chamber surfaces before builds. These blowdowns are generally less than a few seconds, and the oxidized dust/powder layers are normally less than $\frac{1}{32}$ of an inch thick. While the compressed air from these handheld cans could produce dust clouds, the short air burst durations, small fugitive layer concentrations, and limited discharge pressures should limit the suspended dust/powder concentrations below MEC. The level of dust/powder oxidation should also minimize the combustibility and explosibility of any suspended dust clouds. However, the use of these compressed air cans should be evaluated during the DHA.

A.22.15.3.6.5.6 Oftentimes, these means are gloves that can reach into the build chamber and mechanically remove the residual powder.

A.22.15.3.6.6 The DHA portion of the post-processing operations for recovered powders should include an assessment of the potential change in combustibility properties of the recovered powders or filtrate compared to the virgin powder. For

example, most nickel-chromium alloy powders are non-explosible. However, additive manufacturing condensate of these alloy powders on filters can smolder and cause small fires. Other examples are carbon steels or 316 stainless steel.

A.22.15.3.6.6.1 Because of the ability to print almost any configuration, completed parts should be expected to contain loose powder within internal cavities. The completed part can be rotated several times within the chamber to allow the loose powder to be extracted. It is preferred for this to be done within the printer within an inerted atmosphere.

A.22.15.4.1 The enclosure for object cleaning could be considered unclassified when exhaust ventilation is high. For classification of the enclosure or the surrounding area, see NFPA 499.

A.22.15.4.5 Proper use of the cleaning equipment can prevent the free fall of powder during cleaning operations, which reduces the potential for dust clouds. When natural fiber brushes are used for cleaning, gentle rather than forceful strokes should be used to direct the powder to the collection device.

See A.22.15.3.6.5.2 for a discussion of using compressed air to clean printer parts.

A.22.15.5.2 Printer operators and other AM personnel frequently wear NFPA 2112-certified lab coats while working with metal alloy powders or changing/passivating the metal vapor condensate filter media. These lab coats can protect employees' extremities from the spontaneous flash fires by preventing clothing ignition, which minimizes the potential severity and amount of burn injuries. A flame-resistant lab coat by itself does not meet the requirements for flame-resistant garments in this standard because the flash fire generated during passivation can propagate from the ground level up. The effectiveness of these lab coats and the need for FR undergarments is task-dependent and should be evaluated and documented through PPE hazard assessments.

A.22.15.5.4 During builds, the integrated filter media are designed to remove the nanometal and soot particulates, often referred to as *condensate*, from the waste inert gas stream so that the "clean" inert gas can be recirculated back into the process chamber.

Unlike direct energy deposition (DED), electron beam melting (EBM), cold spray, and similar processes that use combustible metal alloy powders up to 150 μm , traditional powder bed printing processes use aluminum and titanium alloy powders with minimal agglomeration (i.e., clumping) and average particle sizes near 45 μm . As the particle size of the processed powders is increased, the quantity of metal vapor condensate generated inside the process chamber and conveyed to the filter media should decrease (and vice versa). Due to the lack of peer-reviewed studies and documented testing data, the precise autoignition temperature and reaction rates of aluminum and titanium metal vapor condensates are unknown. However, evidence obtained from previous DHAs and known flash fire and smoldering incidents infers these nonpassivated condensates do not immediately react in air.

Despite effective electrostatic controls, dry aluminum and titanium condensate are extremely susceptible to spontaneous combustion and have an extensive history of generating numerous flash fires when passivated or disturbed in ambient or noninerted atmospheres above the LOC. While wet passiva-

tion methods are preferred, solid dry materials like silica sand and chalk are sometimes used to passivate the metal vapor condensate through dilution. Although these materials are noncombustible dusts, the effectiveness of diluting the varying quantities of condensate by simply pouring these materials onto the filter media surfaces and inside the collection containers with minimal mixing is questionable. The printer and other equipment manufacturers who recommend these dry passivation techniques have not determined what effect, if any, these quantities of sand and chalk have on the explosibility of a known quantity of condensate by testing representative samples using ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*. Even if the solid noncombustible material, metal alloy particulate, and condensate are homogeneously mixed, it is unknown if the necessary ratio is achieved and maintained to render the mixture noncombustible and nonreactive. To alleviate these unknowns and mitigate the spontaneous flash fire hazard associated with the metal vapor condensate, noncombustible mineral oil or water should be added to the filter surfaces and collection containers in lieu of or in combination with the dry noncombustible materials.

In addition to the known flash fire and smoldering incidents associated with cleaning, changing, and passivating the condensate filter media and collection containers, additional deflagrations and explosions have occurred while at treatment, storage, and disposal facilities (TSDFs) while shredding or crushing containers and drums containing dry, nonpassivated metal vapor condensate. Therefore, the spontaneous combustion and flash fire hazards associated with the dry condensate should also be documented on the waste profile that is submitted to the TSDF.

A.22.15.6 Equipment pertinent to this section includes auxiliary and cleaning equipment, as well as the 3D printer itself. Since operating instructions and manuals for this equipment are often translations from other languages besides English, they should be verified to be understandable in English or the language(s) understandable to the operator. Several equipment manufacturers provide equipment-specific training courses and offer certifications for operators that have been adequately trained for the safe operation of the equipment, maintenance of the equipment, or both.

A.22.15.6.1 A qualified person approach can be considered if this training is not available.

The operating manuals often contain requirements or guidance that are not required by consensus standards but are important for the proper and safe operation of the equipment.

A.22.15.6.2 Training is an important element of safely operating and understanding the hazards associated with powders. The equipment manufacturer should provide training on the operation of equipment; however, equipment manufacturers should not be relied upon for the general assessment and mitigation of combustible and explosive powder hazards. Similarly, SDS are often incomplete in regard to combustible dust hazard specifications in printing applications.

In-house training should be performed by an equipment-manufacturer-certified trainer or training personnel.

A.22.15.7.2 Emergency responders will make decisions based on the information provided on the machines. It is important that emergency responders understand the posted signage. Generally, it is better to spell out the powder composition

rather than use chemical abbreviations that might not be understood by emergency responders.

A.22.16.1 Finely divided dry alkali metals and finely divided alkali metals dispersed in an ignitable (flammable or combustible) liquid can exhibit pyrophoric properties. Prior to the handling of these materials, the vendor of the alkali metals, alkali metals alloy, or alkali metals dispersion should be consulted for safe practices. These practices include the design of the facilities for storage and handling of these materials, protective clothing requirements, training requirements, and general safety precautions.

Dry alkali metals and alkali metal alloy powders are pyrophoric in nature and water reactive. Precautions are required because, on exposure to air, the powders can ignite or explode.

Dispersions of alkali metals and dispersions of some alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to reactive metals, solvents present the concerns of ignitable (flammable or combustible) liquids and vapors. The SDS provided by the supplier of the material, NFPA 30, and NFPA 77 are applicable to addressing the problems of ignitable (flammable or combustible) liquids and vapors.

A.22.16.1.2.1 Alkali metals react with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction vary with the conditions; therefore, the best approach is to take precautions to keep moisture away from alkali metals.

A.22.16.1.3.1 Alkali metals in contact with moisture form alkali metal hydroxides and alkali metal oxides, which will cause caustic burns. Alkali metals in contact with human skin will react with body moisture and cause thermal and caustic burns.

A.22.16.1.3.2 Hazards involved with handling molten alkali metals are significantly greater than those involved with handling solid alkali metals due to enhanced reactivity, heat of reaction, and elevated temperatures.

A.22.16.1.3.2.2 Fire risk is significantly reduced when the outer clothing layer is kept dry.

A.22.16.1.4.1 Thermite reactions are extremely exothermic, [e.g., temperatures in excess of 4000°F (2204°C)]. A thermite reaction typically occurs between one metal oxide and another metal which reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.22.16.2.1.1 Floor drains typically are connected to systems that contain water, which when in contact with an alkali metal will result in a violent reaction.

A.22.16.2.2.2 The plan should include specific actions in the event of an alkali metal fire and should be coordinated with the local facility management, responding firefighters, and medical personnel.

The plan should pay special attention to the extreme hazards associated with alkali metal–water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning alkali metals are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent alkali metals fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with alkali metals know its hazards. Such personnel will have the greatest ability to extinguish an alkali metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

An alkali metal at room temperature and in the presence of incompatible materials can reach its melting point and the autoignition temperature.

The degree of reaction and the amount of time to produce the melting point and autoignition temperature vary with surrounding conditions, with the temperature of the exposed alkali metals being the major factor. At low temperatures or temperatures within a few degrees of the melting point of the alkali metal, the reaction is slower and with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting an alkali metal fire, it is important that fire-fighters be aware of the dangers of burning alkali metal. When molten alkali metal reacts with materials such as water or ignitable (flammable or combustible) liquids or gases, molten alkali metal can be ejected a considerable distance. The severity of alkali metal reactions varies with a multitude of conditions.

An alkali metal in contact with moisture and air forms alkali metal hydroxides and alkali metal oxides, which will cause caustic burns if personnel do not have adequate personal protective equipment.

A.22.16.3.2.1 Organic materials in the presence of oxides of potassium or NaK can create an explosive, shock-sensitive mixture.

A.22.16.6.1.1 Dispersions of alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, solvents present the concerns of ignitable (flammable or combustible) liquids and vapors. The SDS provided by the supplier of the material, NFPA 30, and NFPA 77 are applicable to addressing the problems of ignitable (flammable or combustible) liquids and vapors.

A.22.16.6.1.2.2 Organic materials in the presence of oxides of potassium or NaK can create an explosive shock-sensitive mixture.

A.22.16.6.1.2.3 Solid alkali metals are supplied in a variety of forms (e.g., ingots and ribbon), which are often individually protected in small cans or airtight foil pouches. If individual containers are not supplied and the containers are opened, alkali metal is exposed to surrounding air, causing slow reactions to take place. It is for this reason that, once the container is opened, only the amount of alkali metal intended to be used

should be removed and the container should be immediately resealed.

A.22.16.6.1.2.4 If left open for more than 15 minutes, the container should be purged with a gas that is inert to alkali metals.

A.22.16.6.4.1.4 See A.22.16.8.1.2.1(C).

A.22.16.6.4.1.6 In the assessment of the amounts needed for process use, risks and fire exposures should be evaluated with other processing requirements. Alkali metals in containers staged for melting should be considered process vessels.

A.22.16.7 Subsection 22.16.7 applies to operations where alkali or alkali alloys are subjected to processing or finishing operations. The operations specified in 22.16.7 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

A.22.16.8.1 A number of small buildings or structures separated from each other, as opposed to a single larger building, reduce the risks associated with handling and processing alkali metals. In the event of an uncontrolled alkali metals emergency, property damage would be comparatively reduced.

A.22.16.8.1.2.1(A) Alkali metal is shipped from alkali metals manufacturers in UN specification containers that should continue to act as storage containers. Containers should be sealed to remain airtight, with the alkali metal coated with mineral oil or packed under an argon cover. Containers used to store alkali metals under mineral oil for long-term storage (over 3 months) should be inverted to redistribute the mineral oil covering the alkali metal. Containers packed under an argon cover should be checked regularly to verify the integrity of the container seal. When alkali metal is returned to any shipping container, the protective method used by the manufacturer should be duplicated.

A.22.16.8.1.2.1(C) Alkali metals are known to be incompatible with the following materials:

- (1) Inorganic and organic acids
- (2) Halon 1211
- (3) Halon 2402
- (4) Carbon tetrachloride
- (5) 1,1,1-trichloroethane
- (6) Oxidizers such as nitric acid
- (7) Chromic acid
- (8) Phosphoric acid
- (9) Hypochlorous acid
- (10) Reducing acids such as sulfuric, hydrochloric, and sulfamic acid
- (11) Mineral oil for NaK
- (12) Halogenated hydrocarbons
- (13) Water
- (14) Alcohols
- (15) Carbon dioxide

Oxalic acid, phenol and organic acid mixtures, and compounds such as paint strippers or metal cleaners are also reactive and should not be stored in the vicinity of an alkali metal.

A.22.16.9 Alkali metal fire residue products can include metallic alkali metals, alkali metal nitrides, alkali metal oxides, or alkali metal hydroxides, which can absorb moisture.

A.22.16.9.1.1 Once an alkali metal fire is extinguished, alkali metal is usually still present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of alkali metals. Alkali metal fire residues can include other reactive components. These residues can react with each other and cause re-ignition. Containers of residues can be purged with argon gas, or the residues can be coated with water-free mineral oil to reduce the potential for reaction. Under solid waste environmental regulations, these residues could be considered a hazardous waste and could be subject to hazardous waste packaging, storage, notification, and disposal regulations.

A.22.16.9.2.2 Alkali metals react with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction vary with the conditions; therefore, the best approach is to take precautions to keep moisture away from alkali metals.

A.22.16.9.3.2.1 The longer the material is stored, the greater the risk of hazardous reactions.

A.22.16.9.4 Attention is called to the hazardous conditions that could exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around metal powder plants.

A.22.17.1 The overall organization has been to group common operations. Additional hazards or requirements for specific legacy metals are at the end of each section.

A.22.17.1.2 The reaction of water and water reactive metals produces hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.22.17.1.3 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 4000°F (2204°C)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine legacy metals particulates, especially powder, and molten legacy metals, although there are documented instances of legacy metals grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to legacy metals and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with legacy metals have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.22.17.1.4 For practical consideration, a eutectic reaction involving legacy metals is one involving another metal, usually with an iron or nickel base, where the mixture melts at a lower temperature than either of the individual metals.

A.22.17.1.7.2 An inert gas chamber, commonly known as a dry welding box, or glove box, is typically used for performing legacy metal-welding operations. Such equipment is often

equipped with a mechanical vacuum pump system with an inert gas backfilling and purging system to effect evacuation of the chamber and provide a regulated supply of inert gas at or slightly above atmospheric pressure. For further information, consult the equipment manufacturers or the American Glove-box Society.

Cleaning methodologies should consider the hazards of generating airborne dusts and the dangers associated with the use of vacuum cleaners.

A.22.17.3.3 Chips, turnings, powders, or swarf that is being preheated or charged to melting pots will autoignite at temperatures below that of the solid metal. Solids should be free of these smaller particles, which can ignite and, in turn, ignite the solids. There should be no depression directly beneath the metal storage area where water can accumulate or flow during a fire.

A.22.17.3.3.1 The contact of moisture with molten metal can result in a violent explosive reaction with the generation of steam or hydrogen. It is important to establish and document a method of preheating that heats all material to a minimum temperature of 250°F (121°C) to ensure the removal of moisture. A higher heating temperature might be necessary if the metal is contaminated with corrosion products, salts, or other foreign materials. Molds or tools that will come into contact with molten magnesium should be similarly preheated.

A.22.17.3.3.3 Iron scale and molten metal can create a thermite reaction. The interior of a crucible furnace, normally known as the *setting*, is a critical area of concern. With the use of sulfur hexafluoride (SF₆) and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern.

A.22.17.3.3.8 Entrance of water into the furnace chamber is the primary cause of both steam and hydrogen explosions. Features to reduce or eliminate the entrance of water into the furnace chamber should be incorporated into the design of new equipment or modifications to older equipment. Examples are the use of sodium-potassium alloy (NaK) for cooling media, which has hazards of its own to consider. Newly created hazards should be weighed against the hazards potentially eliminated before incorporating the changes in practice.

A.22.17.3.3.10.1 The explosion that can occur due to the rapid phase transformation (liquid to gas) of water trapped below molten metal takes place over a span of 10⁻⁵ seconds to 10⁻⁴ seconds. This time span is faster than a condensed phase detonation. The required pressure-relieving device would not be effective in relieving the rapid pressure buildup caused by the rapid transformation of water trapped below molten metal. The required device is intended to safely relieve only a much slower buildup of pressure, such as might occur from small incursions of water onto the surface of the molten metal.

A.22.17.3.3.10.4 Sudden rises in pressure are an indication of the onset of a steam or hydrogen-oxygen explosion in the furnace. The normal operating range and rates of rise in pressure for the process should be determined as part of the process control function. High-pressure and rate-of-rise-in-pressure interlocks should be installed to shut off the power to the process when they are activated. Continuation of heat to the process will continue the generation of molten niobium and result in more hydrogen or steam, or both.

The process operating parameters should be continuously monitored for abnormal conditions. Waterflow, temperature, and pressure on the cooling system are critical for maintaining the correct cooling conditions. Furnace pressure can provide early warning of abnormal conditions in the furnace chamber. Use of data acquisition to monitor the process is the most effective way to oversee the many parameters that could be of interest. Automatic alarms that warn operators of abnormal conditions are also beneficial. Where a parameter is deemed critical or an indicator of an extreme safety hazard, the use of interlocks to terminate the process is the best course of action.

A.22.17.3.3.11 The collection of moisture in a mold could cause the metal in a molten form to react, causing a fire or explosion.

A.22.17.3.3.11.1 Hazards analyses can be used to determine the minimum wall thicknesses required for safe operation. Several catastrophic incidents have occurred due to failure to prevent the interaction between molten metals and water.

A.22.17.3.3.12 Furnace residues produced in a vacuum or inert gas atmosphere are finely divided powders that have not been exposed to an oxidizing atmosphere. Legacy metals have a high affinity for oxygen and will oxidize until a sufficiently thick oxide layer has formed. If the oxide layer is formed in a controlled manner, the process is called passivation. If the oxide layer is formed in an uncontrolled manner, it simply burns due to the exothermic nature of oxidation.

Condensed furnace residues, by nature, are extremely fine on the order of submicron size and will oxidize more rapidly and generate more heat than powders with large particle size distributions.

After the furnace has cooled to ambient temperature, the use of passivation cycles, in which controlled amounts of air are introduced into the furnace, will render the material stable. An alternative is to burn the material completely while it is contained in the furnace, followed by cooling it to ambient temperature. Burning will result in the complete oxidation of the residue and eliminate the potential for further oxidation.

After passivation or burning of the furnace residue is completed, the material should be placed in covered drums and moved to a designated safe storage location.

A.22.17.3.3.14.1 The furnace and crucible assembly should be located in a protective bunker that will direct the explosion away from operating personnel in adjacent areas. Isolation of the furnaces and remote operation remove operating personnel from the immediate vicinity of the furnace and reduce the risk of severe injury if an explosion occurs.

A.22.17.3.3.14.2 Locating control consoles away from the immediate vicinity of melting furnaces reduces the risk of injury if an explosion occurs. The distance from the furnace should be determined on a case-by-case basis by assessing the potential, magnitude, and expected path of an explosion. The best sources of technical expertise are the furnace manufacturers; they should consider the issue of remote location of control consoles for any new or modified niobium melting furnace.

A.22.17.3.3.14.3 In vacuum arc remelting furnaces, arcing of the electrode to the mold wall is the primary cause of water being introduced into the chamber. To minimize the risk of arcing, the electrode should be straight and of uniform cross

section to maintain the clearance between the electrode and the mold wall. Additionally, use of magnetic fields should be considered to deflect the arc away from the mold wall. Use of an electromagnetic field to contain the arc and to prevent arcing to the crucible is standard practice in vacuum arc remelting.

A.22.17.4.1.4 Transportation regulations, including but not limited to the US Department of Transportation Hazardous Materials Regulations (49 CFR Parts 171–178), allow the use of various containers for the transportation of combustible metals. Not all containers specified in the regulations are conductive. Care should be taken to ensure that all containers selected for shipping comply with this chapter, in addition to regulations governing the transportation of hazardous materials.

A.22.17.4.9.4 Temperature-sensing elements connected to alarms or machine stop switches can be employed in locations where overheating of bearings or other elements is anticipated.

A.22.17.4.10.2 See NFPA 77.

A.22.17.4.10.2.2 The term *static-conductive* is often used interchangeably with *static-dissipative* in the industry that supports this equipment.

A.22.17.4.10.3 Bearings located outside the air volume containing metal dust are preferred. Bearings within the air volume containing metal dust are potential sources of ignition in the event of a failure.

A.22.17.4.14 The quantity of powders stored in manufacturing operations and areas should be minimized. The quantity should be limited to that needed to continue the operation or process.

A.22.17.4.17.1 Legacy metals oxidize readily at elevated temperatures.

The sensitivity of powder to ignition through contact with hot surfaces or exposure to hot environments while in an oxygen-containing environment such as air is directly proportional to the surface area of the powder. Even low-surface-area powders are sensitive to exposure in air to hot environments. Historically, it has been determined that powders such as tantalum should not be exposed to atmospheres containing oxygen at temperatures above 176°F (80°C). Above that temperature, even passivated powders have been shown to continue to oxidize. Intermediate- and high-surface powders should not be exposed to hot surfaces at 176°F (80°C). Lower temperatures should be employed, not exceeding the temperature at which the powder oxidizes.

A.22.17.4.17.3 If inert atmosphere drying or vacuum drying are chosen as the most appropriate style of drying, care must be taken to ensure that the powder is cooled below the oxidizing temperature prior to re-exposing the powder to air atmosphere. Heated powder oxidizes at a high rate when exposed to air at elevated temperatures.

A.22.17.4.19 Care should be exercised in selection of the type of dryer used to dry powders. Electric resistance element dryers should not be used due to the risk of dust particles coming in contact with the heating elements and igniting. If dryers are outfitted with glass windows for the viewing of dryer contents, such windows should be covered with metal mesh reinforcement or external shielding to prevent the possibility of glass projectiles or other missile hazards resulting from an explo-

sion. Dryer types include tray, drum, rotary, fluidized-bed, pneumatic, spray, and vacuum types.

Additionally, a hazards analysis should be conducted to determine the safest method of drying based on the specific materials to be dried. Fine surface-area powders are very sensitive to self-heating. Coarse, particle-size powders are much less sensitive to drying conditions. Drying parameters — both the type of drying and the specific conditions of drying [i.e., temperature, bed height, drying gas atmosphere (air atmosphere or inert gas)] — need to be assessed in light of the specific powders to be dried.

A.22.17.4.19.4 Consideration should be given to a hazards analysis for a wet collection system installation.

A.22.17.4.19.7 Dryer control systems are critical components that provide safety during drying operations. The reliability of the microprocessor controllers should be monitored on a regular basis (e.g., daily or weekly) consistent with manufacturers recommendations or the applicable safety instrumented function design. Temperature overshoots can result in dangerous conditions that might allow dryer chamber temperatures to exceed the oxidation temperature of the metal. The reliability of fan controls should be monitored and the thermocouples should be calibrated on a regular basis to ensure correct and safe operation.

A.22.17.4.19.9(5) When powder is dried in atmospheres containing oxygen, it is recommended that the dryer be outfitted with a means to allow the introduction of an inerting agent. Because several powders undergo, under certain conditions, a highly exothermic reaction with nitrogen, nitrogen might not be an appropriate inerting agent. The inerting agent of choice is often argon or helium. Because of dryer design and configuration, it is sometimes difficult and awkward to use other appropriate extinguishing materials in the event of a dryer fire. Historically the use of argon gas in extinguishing a fire has proven to be very effective.

A.22.17.4.20.2 The presence of moisture in air reduces surface resistivity of many materials in process areas where powders are handled, thereby reducing general electrostatic discharge (ESD) ignition risk.

A.22.17.4.22.1 Deflagration venting is especially important for combustible dust, due to the high maximum explosion pressures reached and the extremely high rate of pressure rise. For information on the design of deflagration vents and predicting the size of the fireball, see NFPA 68. Dust collectors, when provided by a manufacturer, seldom have properly sized venting to handle a combustible dust explosion.

In processes where the component part consists of a variety of materials and it is not possible to segregate the combustible metal component during the finishing process, it should be noted that this mix of metals presents an additional hazard in the process ventilation equipment. Daily inspection, cleaning, and general maintenance of the system must be performed to minimize exposure to inherent risks when performing finishing procedures on these types of parts. All equipment should be bonded and grounded in accordance with NFPA 77.

A means to determine protection requirements should be based on a risk evaluation, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combusti-

ble concentration, and recognized potential ignition sources. See AICHE, *Guidelines for Hazard Evaluation Procedures*.

The following items are areas of concern during the design and installation of process equipment:

- (1) Elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth
- (2) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and the building or room
- (3) Proper classification of electrical equipment for the area and conditions
- (4) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings
- (5) Use of electrically conductive belting, low-speed belts, and short center drives as a means of reducing static electricity accumulation
- (6) When power is transmitted to apparatus within the processing room by a belt or chain, the belt or chain should be encased in a practically dusttight enclosure, constructed of substantial, noncombustible material that should be maintained under positive air pressure. Where power is transmitted by means of shafts, the shafts should pass through close-fitting shaft holes in walls or partitions.

A.22.17.4.22.2(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The length of the relief duct should be restricted to not more than 20 ft (6 m).

A.22.17.4.22.2(3) Ductwork provided with explosion isolation systems identified in NFPA 69, which can prevent propagation of a deflagration into other parts of the process, is not subject to NFPA 68.

A.22.17.4.22.2(5) This method is limited in effectiveness because of the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A.22.17.4.23 The use of inert gas for all machinery is highly recommended. All typical operations encountered in the processing of powder produce ignition sources (mechanical friction, impact sparks, hot surfaces, and potentially electrostatic discharge). As such, the primary basis of safety should be the exclusion of oxygen from the atmosphere under which powder is processed.

A.22.17.4.24.2 Where personnel are working on suitable static-dissipative or conductive flooring, they should be wearing appropriate footwear. Footwear having resistance in the range of 1×10^6 ohms to 1×10^8 ohms is considered to be static-dissipative. Generally, it is recommended that personnel limit the conductivity of their footwear to the range of 5×10^4 ohms to 1×10^8 ohms. This accomplishes grounding of static discharge from the operator but reduces the potential risk of electrocution. All personnel should be electrically grounded when they are working in an environment containing a material possessing an MIE of 100 mJ or less.

A.22.17.4.24.5 Unauthorized personnel should not be permitted in powder-handling areas. Identifying authorized personnel is determined by the individual company. Authorized personnel are people experienced and knowledgeable in hazards asso-

ciated with niobium powders. The intent of the requirement is to prevent people who are not familiar with the hazards associated with niobium powders from wandering through a production area. This requirement does not preclude such a person from being escorted by authorized personnel.

A.22.17.5.4 Certain nondusting grades of aluminum flake powder are being produced. These powders tend to reduce the hazard of inadvertently caused dust clouds. They are as combustible as regular grades of flake powder and, once levitated into a cloud, exhibit the same explosibility characteristics. For those reasons, the same precautions must be observed as for normal grades of powder.

A.22.17.5.6 The following are considered spark resistant and appropriate for use:

- (1) Beryllium-copper
- (2) Brass
- (3) Phosphorous bronze

Aluminum should not be used because of the potential for thermite sparks. Thermite sparks can occur with aluminum, magnesium, tantalum, titanium, or their alloys in the presence of oxygen carriers such as iron or lead oxide. Thermite sparks are highly incandescent (and energetic) sparks that are white hot.

In the manufacture of product from powder, it might be necessary to mix the powder with other additives or to pour the powder from one container to another. Both of these operations tend to produce a dust cloud. A hazards analysis should be done on any operation that produces a dust cloud.

If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing the operations should be wearing flame-retardant clothing, wearing static-dissipative shoes, and standing on static-dissipative floor covering or static-dissipative floor mats.

If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing will not be necessary. However, static-dissipative footwear, static dissipative floor covering, or both should be used.

A.22.17.5.7 Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary, depending on the type of combustible dust and processing methods used.

A.22.17.5.10 Static-dissipating flooring is often employed in metal manufacturing and processing plants. However, it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available methods. Careful examination of the details of this chapter will disclose the logic of the use of conductive flooring materials.

The surface of a static-dissipating floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges.

The maximum resistance of a static-dissipating floor is usually less than 10^6 ohms, as measured between two electrodes placed 3 ft (0.9 m) apart at any points on the floor. The minimum resistance is usually greater than 2.5×10^4 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks.

Resistance values are checked at regular intervals, usually once each month.

Refer to *NFPA 70* for equipment and procedures that are acceptable practice for testing for minimum and maximum resistance. Measurements should be made at five or more locations in each room, and results can be averaged.

For compliance with the maximum resistance limit, the average of all measurements should be less than 10^6 ohms.

For compliance with the minimum resistance limit, one individual measurement should be less than 10^5 ohms, and the average of not fewer than five measurements should be greater than 2.5×10^4 ohms.

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 3 ft (0.9 m) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

A.22.17.5.12 See the discussion under A.22.17.5.10.

A.22.17.5.12.4.1 In the manufacturing of product from powder, it might be necessary to mix the powder with other additives or to pour the powder from one container to another. Both of these operations tend to produce dust clouds. A hazards analysis should be done on any operation that produces a dust cloud. If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing these operations should wear flame-retardant clothing, wear static-dissipative shoes, and stand on a static-dissipative floor covering or static-dissipative floor mats. If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing is not necessary. However, static-dissipative footwear, a static dissipative floor covering, or both should be used.

A.22.17.5.12.9 Compacted powder, when heat-treated under argon or a vacuum, behaves in a similar fashion to powder. When heat-treated, the passivated oxide film present on the surface of each particle comprising the compact diffuses into the center of each particle.

On removal from the heat treatment furnace, the passivated oxide film should be re-established through exposure to air. Because the oxidation of the powder generates heat, it is important that the temperature of the compact be below 122°F (50°C) when the compact is exposed to air. This practice prevents the re-oxidation of the compact from proceeding at such a rate that the compact becomes too hot. If the compact becomes too hot, a risk of ignition and fire will exist. Separating the trays of compacts further reduces the risk by providing uniform exposure to air and prevents localized hot spots from developing. It is essential to ensure that all particle surfaces become re-oxidized prior to further processing of the heat-treated compacts.

A.22.17.5.12.9.1 Compacts after furnacing might also require passivation.

A.22.17.6.1.1 Dispersions of metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, solvents present the concerns of ignitable (flammable or combustible) liquids and vapors. The SDS provided by the supplier of the material, NFPA 30, and NFPA 77 are applicable to addressing the problems of ignitable (flammable or combustible) liquids and vapors.

A.22.17.6.2.2 This requirement is applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled, such as in finishing and polishing equipment, filters, driers, dust screens, fixed storage bins, and dust collection and transport systems of all types. For further information on bonding and grounding, see NFPA 77.

A.22.17.6.2.4 When metal is milled in a ball or rod or similar type of mill in the presence of a liquid that is chemically inert with respect to the metal, the air-dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air, any unoxidized surfaces produced during milling will react and could generate enough heat to cause ignition. To prevent ignition, it is imperative that a controlled amount of oxygen be present in the milling operation and in slurries ahead of filters and blenders so that new surfaces are oxidized as they are formed. The addition of a milling agent, such as stearic acid, does not eliminate the need for this added oxygen.

A.22.17.6.2.4.1 See A.22.17.6.2.4.

A.22.17.6.2.4.2 See A.22.17.6.2.4.

A.22.17.6.2.4.4 Of particular note in the metal paste manufacturing process are the risks associated with hybrid mixtures. A hybrid mixture is a mixture of a dust with one or more flammable gases or vapors. The presence of a flammable gas or vapor, even at concentrations less than its LFL, will not only add to the violence of the dust-air combustion but will drastically reduce the ignition energy. In such cases, electrical equipment should be specified that is suitable for simultaneous exposure to both Class I (flammable gas) and Class II (combustible dust) hazards.

A.22.17.6.4.1 See Figure A.22.17.6.4.1(a) and Figure A.22.17.6.4.1(b) for examples of dust collection at bag dump stations.

Since the combustible metal portions of parts and components can exhibit the burning characteristics of the combustible metal when involved in a fire, storage plans and arrangements should be designed to mitigate the fire hazards associated with burning the combustible metal. Assemblies in which the combustible metal is a minority component might or might not exhibit burning behavior similar to a fire involving pure combustible metal, depending on the following:

- (1) Whether or not the combustible metal is exposed on the outside of the assembly
- (2) How fast or how completely the packaging material might burn away to expose the combustible metal
- (3) Height and arrangement of the storage array
- (4) Intensity of any exposure fire
- (5) Rapidity with which automatic protection systems might respond to control the initial fire, thus preventing the involvement of the combustible metal. The best method to determine the level of hazard is with a properly designed fire test.

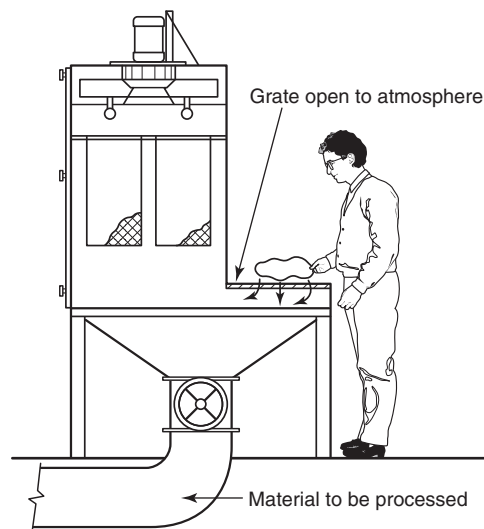


FIGURE A.22.17.6.4.1(a) Example of Unacceptable Manual Bag Dump Station in Which Operator Is Exposed to Potential Fire or Explosion.

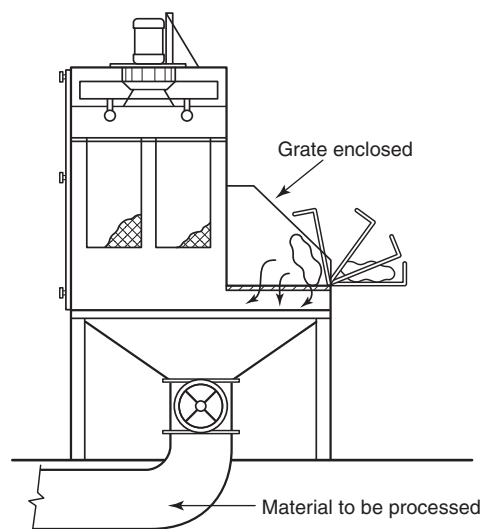


FIGURE A.22.17.6.4.1(b) Example of Acceptable Station in Which Bag Dump Operation Is Automatic.

A.22.17.7 Subsection 22.17.7 applies to operations where metals or metal alloys are subjected to processing or finishing operations. The operations can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

The same basic prevention measures apply to both metals fires and explosions in mill operations. The prevention measures are good housekeeping, elimination of ignition sources, isolation of dust-producing operations and subdivision of large operations, and education of employees regarding hazards.

The basic protection measure against fire hazards is the installation of fixed automatic protection equipment. An important consideration is the ability of the fire protection system to function after an explosion. Suppression systems detect the explosion, suppress it, and extinguish it before dangerous pressures are developed. The pressure wave of an explosion travels at 1100 ft/sec (335 m/sec), which puts it well ahead of the flame front, which travels at 4 ft/sec to 6 ft/sec (1.2 m/sec to 1.8 m/sec). The equipment for suppression consists of the pressure detector, control unit, and appropriate extinguishing agent. The suppressant should block inlets and outlets, as well as flood the vessel.

Inerting is the preferred approach for protecting against fire and explosion, because it does not allow ignition to occur. Inerting consists of lowering the oxygen concentration below the point where it can support an ignition. A successful inerting system requires a good method of control to insert the inerting gas into the process, as well as a continuous oxygen analyzer to monitor and shut down the system.

Mill operations processes are a source for the accumulation of fines, saw chips, dust, and oily metallic scrap and residue. Ignition sources can be electrical, thermal, or mechanical, or static electricity can be the source.

The control of ignition sources is paramount in maintaining a fire-free environment. The following measures provide guidance for controlling ignition sources:

- (1) Open flames and smoking should be prohibited.
- (2) Cutting and welding in the vicinity of fines, dust, and flammable lubricants should be prohibited.
- (3) Electrical equipment, wiring, and lighting in the area should comply with Article 500 or 506 of *NEPA 70*.
- (4) Blowers and exhaust fans should be suitable for the application. Maintenance should be provided to ensure clearance between the blades and casing.
- (5) All equipment should be grounded and bonded to prevent accumulation of static electricity. Electrical grounding of all equipment and containers should be thorough. Static cannot be grounded through an oil or grease film in bearings; therefore, it is necessary to provide wire jumpers around lubricating films.
- (6) Sparks caused by metal striking metal should be eliminated.
- (7) All sources of mechanical friction should be minimized.
- (8) Magnetic separators or screens should be provided to prevent foreign objects from entering grinders, pulverizers, crushers, or other milling equipment.
- (9) Nonsparking types of tools should be utilized. Friction caused by hammering, sliding, or rubbing should be avoided.
- (10) Individual dust collection systems should be provided for each piece of equipment as much as practical.
- (11) Dust-handling equipment should be located adjacent to exterior building walls. Locations in basements should be avoided.

A.22.17.7.2 Flashing of chips during machining should be minimized by any of the following methods:

- (1) Keeping the surface speed below 300 ft/min (1.5 m/sec) or above 2200 ft/min (11 m/sec)
- (2) Increasing the feed rate from 0.0008 in. to 0.010 in. (0.02 mm to 0.25 mm) per revolution

- (3) Controlling the relative humidity in the machining area to 45 percent or lower at 70°F (21°C) room temperature
- (4) Applying a coolant

A.22.17.7.2.1 The principal fire hazard is the ease of ignition of finely divided combustible material with subsequent ignition of less easily ignited particles.

A second critical source of fire hazards comes from vapors and gases generated by lubricants and solvents used in the processes found in mill operations. The explosion hazard of a dust or vapor is an extension of a fire hazard and can be the source of ignition for fires. Materials used in mill operations should be evaluated for their susceptibility to ignition in a mill operation environment.

A.22.17.7.2.2.1 Improperly designed or dulled tools can produce high temperatures at the tool-metal interface, causing ignition of the turnings if an adequate coolant flow is not used.

A.22.17.7.2.3.3 The principal fire hazard is the ease of ignition of finely divided combustible material with subsequent ignition of the less easily ignited particles.

A.22.17.7.2.4.3 Petroleum oils in any form are susceptible to relatively low ignition temperatures from any source in a mill environment. Practices that prevent ignition should be followed.

A.22.17.7.2.5.2 Petroleum oils in any form are susceptible to relatively low ignition temperatures from any source in a mill environment. Practices that prevent ignition should be followed.

A.22.17.7.2.5.3 Cutting oils with a flashpoint greater than 200°F (93°C) are acceptable with some combustible metals; however, oil-based fluids are rarely seen anymore due to environmental issues. Most water-based fluids are adequate from a quality control and fire standpoint. Most oil-based fluids are used on steel tool machining (drill bits, shears, etc.) due to the lower risk of corrosion.

A.22.17.7.2.5.5 Only mill lubricants with high flash points should be used in rolling and forging operations. All liquids, including lubricants that come into direct contact with the processed metal, pose a fire potential any time the metal heats up to high temperatures in a mill environment in excess of the flash point of the lubricants.

A.22.17.7.3 Subsection 22.17.7.3 applies to operations where magnesium or magnesium alloys are subjected to processing or finishing operations. The operations specified in 22.17.7.3 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

A.22.17.7.3.6 Flashing of chips during machining should be minimized using any of the following methods:

- (1) Keeping the surface speed below 300 ft/min (1.5 m/sec) or above 2200 ft/min (11 m/sec)
- (2) Increasing the feed rate from 0.0008 in. to 0.010 in. (0.02 mm to 0.25 mm) per revolution
- (3) Controlling the relative humidity in the machining area to 45 percent or lower at 70°F (21°C) room temperature
- (4) Applying a coolant

A.22.17.7.3.6.2 Use of high-helix drills prevents frictional heat and possible flash fires in fines. High-helix drills are also recommended for drilling deep holes through composite or sandwich sections.

A.22.17.7.3.7.3 Standard, commercial industrial vacuum cleaners should not be used, because they are not safe for use with magnesium.

A.22.17.7.3.9 Heat treating of magnesium has associated fire risks. To retard ignition of magnesium, mixtures of sulfur dioxide (SO₂), sulfur hexafluoride with carbon dioxide (SF₆/CO₂), helium (He), and argon (Ar) with air are recommended in heat treating furnaces operating above 750°F (399°C).

A.22.17.7.3.9.3 See NFPA 86.

A.22.17.7.3.9.4(B) The secondary set of temperature controls should cut off fuel or power to the heat-treating furnace at a temperature that is only slightly above the desired operating temperature.

A.22.17.7.3.9.7 Extreme care should be taken when heat treating aluminum that contains magnesium alloys, because aluminum additions form a eutectic alloy with considerably lower melting and autoignition temperatures. Failure to identify the alloy can result in heat-treating furnace fires. Magnesium in physical contact with aluminum at an elevated temperature can produce the same effect.

A.22.17.7.3.9.9 Heating magnesium in the presence of oxidizers can result in combustion. Special salt fluxes can be safely used for dip brazing of magnesium.

A.22.17.7.3.9.10 Magnesium and aluminum form a eutectic alloy with considerably lower melting temperatures and autoignition temperatures than either parent metal.

A.22.17.7.3.9.11 There is a potential for a thermite reaction between magnesium or a magnesium alloy and iron oxide at elevated temperatures.

A.22.17.8.1.1 Sufficient separation in bulk storage areas should be maintained between the powders and other materials stored in the same area. Storage of powders intermixed with other combustible materials might cause problems in fighting a fire or ignite as a result of burning materials stored in the same area as the powder. Powder at elevated temperatures is highly reactive to water and can cause a severe fire or explosion.

A.22.17.8.1.6.1 Materials incompatible with metal powder include, but are not limited to, oxidizers, organic peroxides, inorganic acids, and materials identified in the SDS.

A.22.17.8.1.8 Consideration of pallet capacity is critical in the safe stacking of products. Due to the variation in mass of each of the metals, it is important to consider the capacity of the pallets, especially those at the bottom of the stack, when stacking palletized containers. Each container and pallet must be designed to hold the full capacity of the stack above it without being deformed.

A.22.17.8.1.8.3 During an emergency situation, every move adds time to the response. Therefore, it is important to ensure that pallets in a stack or row are readily accessible. Taking into consideration the lift capacity of equipment on site and the depth of the stack, one must be able to access containers within three

movements. This inherently leads to smaller stacks, which can reduce the magnitude of a fire.

A.22.17.8.6.1 Industrial buildings or separate storage areas in which magnesium parts are being stored in quantities greater than 500 lb (227 kg) or where these magnesium parts are the primary hazard should be labeled in accordance with NFPA 704. The labeling serves as a warning for firefighters of the potential risk in the event of an emergency.

A.22.17.8.6.1.3 Storage of magnesium ingots should be on the first or ground floor. Basements or depressions below the magnesium storage area into which water or molten metal can flow should be avoided.

A.22.17.8.6.1.3(F)(2) See NFPA 221 for wall construction details.

A.22.17.8.6.2.3 Storage of magnesium castings should be on the first or ground floor. Basements or depressions below the magnesium cast storage area into which water or molten metal can flow should be avoided.

A.22.17.8.6.2.7 Sprinkler systems are of vital importance in heavy magnesium casting areas that also contain significant amounts of ordinary combustibles, because sprinkler operation can prevent the magnesium from becoming involved in the fire.

A.22.17.8.6.3.5 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium and produce a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be put on prompt fire detection and alarm activation, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13.

A.22.17.8.6.5.4 The wet magnesium should be checked frequently to ensure that it remains totally immersed during storage. Fines that come in contact with water, water-soluble oils, and oils containing more than 0.2 percent fatty acids can generate flammable hydrogen gas. Fines that come in contact with animal or vegetable oils can ignite spontaneously.

A.22.17.8.6.6.6 The safest manner of storage is achieved using no stacking.

A.22.17.8.6.7.1 Because the magnesium portions of parts and components can exhibit the burning characteristics of magnesium when involved in a fire, storage plans and arrangements should be designed to mitigate the fire hazards associated with burning magnesium. Assemblies in which magnesium is a minority component might or might not exhibit burning behavior similar to a fire involving pure magnesium, depending on the following:

- (1) Whether or not the magnesium is exposed on the outside of the assembly
- (2) How fast or how completely the packaging material might burn away to expose the magnesium
- (3) Height and arrangement of magnesium storage (removed intentionally)
- (4) Intensity of any exposure fire
- (5) Rapidity with which automatic protection systems might respond to control the initial fire, thus preventing the involvement of the magnesium

The best method to determine the level of hazard is with a properly designed fire test.

A.22.17.8.6.7.4 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium and produce a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be put on prompt fire detection and alarm activation, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13.

A.22.17.9.5.2.4 Special attention should be given to the segregation of ordinary trash and the routine collection of sponge, chips, and powder from floor sweepings as a function of housekeeping.

A.22.17.9.5.5 Employee health and safety in operations depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

The following are important elements of employee training:

- (1) All employees should be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.
- (2) All employees should be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire-extinguishing equipment.
- (3) All employees should be taught the permissible methods for fighting incipient fires in pastes and for isolating aluminum fires.
- (4) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire should be explained.
- (5) Strict discipline and scrupulous housekeeping should be maintained at all times.
- (6) Attention should be given to employee training and organizational planning to ensure safe and proper evacuation of the area.

A.22.18.1.4.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 4000°F (2204°C)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.22.18.3.2.1 A visual inspection of the cooling water outlet is highly recommended to determine adequate cooling water-flow.

A.22.18.3.2.5 Precast solid metal ingots used in remelting might often have internal voids or shrink cavities that can contain water. The introduction of water into molten metal presents a severe risk for a catastrophic explosive reaction.

The explosion that can occur due to the rapid phase transformation of water trapped below molten material takes place over a time span of approximately 12^{-5} sec to 12^{-4} sec, which is faster than a condensed phase detonation.

A.22.18.5.1.3 Certain non-dusting grades of aluminum flake powder are being produced. These powders tend to reduce the hazard of inadvertently caused dust clouds. They are as combustible as regular grades of flake powder and, once levitated into a cloud, exhibit the same explosibility characteristics. For those reasons, the same precautions must be observed as for normal grades of powder.

A.22.18.5.2.1 Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary depending on the type of combustible dust and processing methods used.

A.22.18.5.2.3 Static-dissipative flooring is often employed in combustible metal manufacturing and processing plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available methods. Careful examination of the details of this chapter will disclose the logic of the use of conductive flooring materials.

The surface of a static-dissipative floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges. The maximum resistance of a static-dissipative floor is usually less than 10^6 ohms, as measured between two electrodes placed 3 ft (0.9 m) apart at any points on the floor. The minimum resistance is usually greater than 2.5×10^4 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks. Resistance values should be checked at regular intervals, usually once each month.

Refer to *NFPA 70* for equipment and procedures that are acceptable practice for testing for minimum and maximum resistance. Measurements should be made at five or more locations in each room, and the results can be averaged.

For compliance with the maximum resistance limit, the average of all measurements should be less than 10^6 ohms.

For compliance with the minimum resistance limit, one individual measurement should be less than 10^5 ohms, and the average of not less than five measurements should be greater than 2.5×10^4 ohms.

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to grounds at that location. Measurements are customarily taken with the electrode or electrodes more than 3 ft (0.9 m) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

A.22.18.5.2.4 Personnel handling metal powder in a procedure that causes the generation of combustible metal dust should wear flame-resistant or flame-retardant clothing.

Flame-resistant clothing does not ignite, because the fibers themselves do not support combustion. Flame-retardant clothing consists of a base material, such as cotton, that is treated with a topical chemical additive to make the fabric resist igni-

tion and to make it self-extinguishing. When a flame touches the clothing, the coating initiates a series of chemical reactions, creating gases to extinguish the flame.

The difference between flame-resistant and flame-retardant clothing is the permanency of the flame resistance. With flame-resistant fibers, the properties are permanent; with flame-retardant fibers, the properties can be laundered out unless specific procedures are followed.

Either fiber will allow a few seconds for the employee to react and escape. Pure cotton and wool, while they are considered flame retardant, are not appropriate for protection from metal fires, because either will allow the accumulation of metal dust within the fiber structure.

A.22.18.5.2.5 The following are considered spark resistant and appropriate for use with metal:

- (1) Beryllium-copper
- (2) Brass
- (3) Phosphorous bronze

Aluminum should not be used because of the potential for thermite sparks. Thermite sparks can occur with aluminum, magnesium, tantalum, titanium, or their alloys in the presence of oxygen carriers such as iron or lead oxide. Thermite sparks are highly incendiary (and energetic) sparks that are white hot.

A.22.18.5.4.1 In the manufacture of product from powder, it might be necessary to mix the metal powder with other additives or to pour the metal powder from one container to another. Both of these operations tend to produce metal dust clouds. A hazards analysis should be done on any operation that produces a dust cloud.

If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing these operations should wear flame-retardant clothing, wear static-dissipative shoes, and stand on static-dissipative floor coverings or static-dissipative floor mats.

If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing will not be necessary. However, static-dissipative footwear, static-dissipative floor coverings, or both should be used.

A.22.18.5.7 See A.22.18.5.4.1.

A.22.18.5.9 Compacted metal powder, when heat treated under argon or vacuum, behaves in a similar fashion to metal powder. When heat treated, the passive oxide film present on the surface of each metal particle making up the compact diffuses into the center of each particle.

Upon removal from the heat treatment furnace, the passive oxide film needs to be re-established through exposure to air. Because the oxidation of metal generates heat, it is important that the temperature of the compact is below 122°F (50°C) when the compact is exposed to air. This practice prevents the reoxidation of the compact from proceeding at such a rate that the compact becomes too hot. If the compact becomes too hot, a risk of ignition and fire exists. Separating the trays of compacts further reduces the risk by providing uniform exposure to air and prevents localized hot spots from developing. It is essential to ensure that all metal particle surfaces become reoxidized prior to further processing of the heat-treated metal compacts.

A.22.18.5.9.1 Some metals compact after furnacing and might also require passivation.

A.22.18.6.1.3 This requirement is applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled, such as in finishing and polishing equipment, filters, driers, dust screens, fixed storage bins, and dust collection and transport systems of all types. For further information on bonding and grounding, see NFPA 77.

A.22.18.6.1.4.1 Journal bearings should not be used because of the difficulty of maintaining proper lubrication to prevent overheating. Outboard bearings are used where practicable because it is easier to check for overheating.

In those instances where dust tends to penetrate bearings, a continuous flow of inert gas (1½ percent to 5 percent oxygen) can be employed to pressurize the bearings and seals.

A.22.18.6.2.1.1 When metal is milled in a ball or rod or similar type of mill in the presence of a liquid that is chemically inert with respect to the metal, the air-dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air, any unoxidized surfaces produced during milling will react and could generate enough heat to cause ignition. To prevent ignition, it is imperative that a controlled amount of oxygen be present in the milling operation and in slurries ahead of filters and blenders, so that new surfaces are oxidized as they are formed. The addition of a milling agent, such as stearic acid, does not eliminate the need for this added oxygen.

A.22.18.6.2.1.1(A) See A.22.18.6.2.1.1.

A.22.18.6.2.1.1(B) See A.22.18.6.2.1.1.

A.22.18.6.2.1.1(E) Of particular note in the metal paste-manufacturing process are the risks associated with hybrid mixtures. A hybrid mixture is a mixture of a dust with one or more flammable gases or vapors. The presence of a flammable gas or vapor, even at concentrations less than its LFL, not only will add to the violence of the dust-air combustion but will drastically reduce the ignition energy. In such cases, electrical equipment should be specified that is suitable for simultaneous exposure to both Class I (flammable gas) and Class II (combustible dust) hazards.

A.22.18.6.2.2.2 See NFPA 499 for information on electrical area classification.

A.22.18.6.4.1 See Figure A.22.18.6.4.1(a) and Figure A.22.18.6.4.1(b) for examples of dust collection at bag dump stations.

A.22.18.7 Subsection 22.18.7 applies to operations where metal or metal alloys are subjected to processing or finishing operations. The operations specified in 22.18.7.1.1 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids.

A.22.18.8.1.6 The safest manner of storage is achieved using no stacking.

A.22.18.8.1.7 Subsection 22.18.8.1.7 applies to the storage of parts and components in warehouses, wholesale facilities, factories, and retail establishments in which metal makes up 50 percent or more of the article's composition on a volumetric basis, or where the metal-containing assemblies, as packaged or stored, exhibit the burning characteristics of metal.

Since the combustible metal portions of parts and components can exhibit the burning characteristics of the combustible metal when involved in a fire, storage plans and arrangements should be designed to mitigate the fire hazards associated with burning the combustible metal.

Assemblies in which the combustible metal is a minority component might or might not exhibit burning behavior similar to a fire involving pure combustible metal, depending on the following:

- (1) Whether or not the combustible metal is exposed on the outside of the assembly
- (2) How fast or how completely the packaging material might burn away to expose the combustible metal
- (3) Height and arrangement of the storage array
- (4) Intensity of any exposure fire

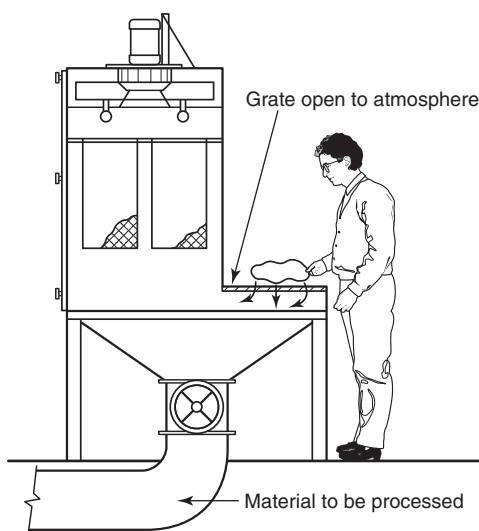


FIGURE A.22.18.6.4.1(a) Example of Unacceptable Manual Bag Dump Station in Which Operator Is Exposed to Potential Fire or Explosion.

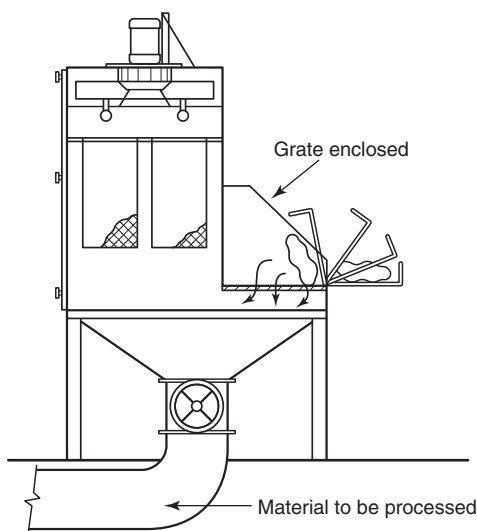


FIGURE A.22.18.6.4.1(b) Example of Acceptable Station in Which Bag Dump Operation Is Automatic.

- (5) Rapidity with which automatic protection systems might respond to control the initial fire, thus preventing the involvement of the combustible metal

The best method to determine the level of hazard is by a properly designed fire test.

A.22.18.8.1.7.3 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section combustible metal and produce a well-involved combustible metal fire before automatic sprinklers operate. Special importance, therefore, should be attached to prompt fire detection and alarm service, design of a fast-operating automatic sprinkler system, and avoidance of obstructions to sprinkler discharge. See NFPA 13.

A.22.18.8.2.1.4 The wet metal should be checked frequently to ensure that it remains totally immersed during storage.

A.22.19.1 Metal recycling facilities receive and process metals for the purposes of re-use or sale. Not all recycling facilities receive, process, or handle combustible metals. Some recycling facilities receive, process, and handle all combustible metals or metal only mixtures. Waste management facilities receive metal waste for the purpose of final disposal by incineration or other methods. Waste management facilities receive metal in all forms and concentrations, including but not limited to; metal only mixtures, mixtures containing combustible metals, and mixtures containing noncombustible metals. Because recycling and waste management facilities vary in scope and scale, the combustible metal hazards vary due to differing process steps. Combustible metals can be delivered for disposal or recycling submerged in water or other fluids and still retain their hazardous properties. Recycling facilities handle and process metals in many forms, the vast majority of which are not reactive.

A.22.19.3.2 Storage in waste management facilities are typically short term depending on the disposal process. Depending on the process capacity of the recycling facility, storage may be short or long term.

A.22.19.3.10 Some combustible metals completely submerged in water are difficult to ignite but may burn more intensely if ignition occurs.

A.22.19.3.12.3 The wet metal should be checked frequently to ensure that it remains totally immersed during storage. Wetted combustible metals will generate hydrogen gas.

A.22.19.4.3 Recycling involves open handling and processing of material. Dust generating processes include but are not limited to re-melt and casting; alloying molten metal; washing; scrap chopping, conveyance, shredding, handling, and sawing; and so forth. Sampling strategies should consider collection of samples from different heights within the plant where dust is generated because lighter, small particle size dust tends to collect higher in the structure.

A.22.19.6.2.1 The reaction of water and aluminum powder produces hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.22.19.6.3.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 4000°F (2204°C)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine aluminum particulate, especially powder, although there are documented instances of aluminum grind-

ing fines initiating such a reaction. The thermite reaction is not necessarily limited to aluminum and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with aluminum have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.22.19.9.2 See Section 22.10 for detailed requirements.

A.22.19.10.1.2 The same metal can be combustible or not combustible, depending on the size or form of the material. During recycling operations, a metal can be converted into a combustible metal through size reduction, separation, or other processes. Processing can include the following:

- (1) Size reduction
- (2) Melting
- (3) Compacting
- (4) Briquetting
- (5) Washing
- (6) Grinding

A.22.19.10.2.4 For information on static electricity, see NFPA 77.

A.22.19.10.2.5.1 Journal bearings should not be used because of the difficulty of maintaining proper lubrication to prevent overheating. Outboard bearings are used where practicable because it is easier to check for overheating. In those instances where dust tends to penetrate bearings, a continuous flow of inert gas (1½ percent to 5 percent oxygen) can be employed to pressurize the bearings and seals.

A.22.19.10.3.1 See Figure A.22.17.6.4.1(a) and Figure A.22.17.6.4.1(b) for examples of dust collection at bag dump stations.

A.22.19.10.6.1 If a sufficient coolant flow is not used, improperly designed or dull tools can produce high temperatures at the tool-workpiece interface, potentially causing ignition of the turnings.

A.22.19.10.6.2 For information on bonding and grounding, see NFPA 77.

A.23.1.1.1 Sulfur differs from most other combustible dusts found in industry in that it has relatively low melting and ignition points. Depending on purity, sulfur melts at or slightly below 246°F (119°C). The ignition temperature of a dust cloud is 374°F (190°C); the ignition temperature of a dust layer is 428°F (220°C). Dilution of sulfur with inert solids is not effective in raising the ignition temperature. Sulfur is handled and processed in the liquid and vapor states in some cases. The liquid is highly combustible, and the vapor is explosive when mixed with air in the proper proportions.

The size reduction process and the finely divided sulfur produced pose severe explosion hazards. Also, mixtures containing finely divided elemental sulfur can be just as hazardous if the sulfur is present in sufficient quantity. Some explosion and fire hazards also accompany the handling and processing of sulfur in bulk in coarse sizes due to the fine dust present.

A.23.7.3.5 See Annex S for an example of application of this method.

A.23.7.3.5.1 The typical range of bulk density for elemental sulfur dust (without additives) is 42 lb/ft³ to 48 lb/ft³. The

layer depth criterion would be approximately ¼ in. (1.7 mm) based on a typical bulk density of rubbermakers sulfur (45 lb/ft³ [720 kg/m³]). If the sulfur at the facility has a different bulk density, the thickness should be corrected for that specific bulk density.

A.23.7.3.5.3 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. This dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

Using a bulk density of 45 lb/ft³ (720 kg/m³), it has been calculated that a dust layer averaging ¼ in. (1.7 mm) thick and covering the floor of a building is sufficient to produce a uniform dust cloud of 0.37 oz/ft³ (370 g/m³) 10 ft (3 m) high throughout the building. This is a conservative value for the optimum concentration with respect to explosion damage potential. This situation is idealized, and several factors should be considered.

First, the layer rarely will be uniform or cover all surfaces. Second, the layer of dust probably will not be dispersed completely by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the ¼ in. (1.7 mm) thick layer is suspended, this material is still sufficient to create an atmosphere within the explosible range of sulfur dusts.

Consideration should be given to the proportion of building volume that could be filled with a combustible dust concentration. The percentage of floor area covered can be used as a measure of the hazard. For example, a 10 ft × 10 ft (3 m × 3 m) room with a ¼ in. (1.7 mm) layer of dust on the floor is obviously hazardous and should be cleaned. This same 100 ft² (9.3 m²) area in a 2025 ft² (188 m²) building is also a moderate hazard. This area represents about 5 percent of the floor area and is about as much coverage as should be allowed in any plant. To gain proper perspective, the overhead beams and ledges also should be considered. Rough calculations show that the available surface area of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

From the preceding information, the following guidelines have been established:

- (1) Dust layers ¼ in. (1.7 mm) thick can be sufficient to warrant immediate cleaning of the area.
- (2) The dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building floor area.
- (3) Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.
- (4) Due consideration should be given to dust that adheres to walls, since it is easily dislodged.
- (5) Attention and consideration should be given to projections such as light fixtures, which can provide surfaces for dust accumulation.
- (6) Dust collection equipment should be monitored to ensure that it is operating effectively. For example, AMS

using bags operate most effectively between limited pressure drops of 2 in. to 5 in. of water (0.5 kPa to 1.24 kPa).

Guidelines (1) through (5) serve to establish a cleaning frequency.

A.23.7.3.6 See Annex S for an example of application of this method.

A.23.7.3.6.1 Figure A.23.7.3.6.1 shows layer thicknesses equivalent to the threshold dust masses according 23.7.3.6.1. As an example of the use of Figure A.23.7.3.6.1 or the equations, the user would initially determine the fractional areas within the facility where significant dust accumulation is occurring or could occur. Using the equations or the chart, the allowable mass would be determined and then converted to an equivalent layer thickness that can be incorporated into the user's routine housekeeping procedure, as required by Chapter 7. Ongoing cleaning would then ensure that the layer thickness within the defined areas of significant dust accumulation was maintained less than the thicknesses determined in the initial assessment.

A.23.7.3.6.2 See A.23.7.3.6.1.

A.23.8.3 Constant supervision by trained personnel (see 8.8.2) is needed because electronic monitoring is not reliable due to the corrosivity of sulfur.

A.23.8.4.2.1.2 Push brooms should have natural bristles.

A.23.8.4.2.6 Because the mixture of sulfur dust and water can corrode materials of construction, the use of steam is discouraged. All the listed precautions in 8.4.2.6.1 might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts.

A.23.8.4.6 See A.25.8.4.6.1 for tables showing unscheduled housekeeping timing based on accumulation for floor-accessible surfaces and remote surfaces.

A.23.8.9 With regards to 8.9.2, qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps or professional licenses.

A.23.8.9.3 With regards to 8.9.3.4, it is suggested that annual meetings be conducted with regular contractors to review the

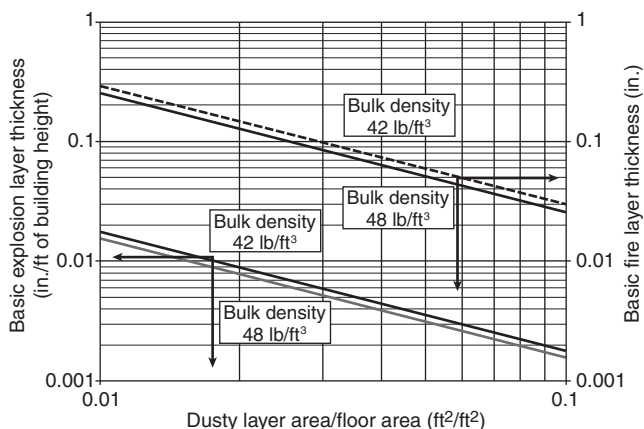


FIGURE A.23.7.3.6.1 Layer Thicknesses Equivalent to the Threshold Dust Masses.

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.

A.23.9.3.1.1 The use of load-bearing walls should be avoided to prevent structural collapse should an explosion occur.

A.23.9.3.1.3.2 It is preferable that the size reduction space be detached. Exterior walls could require deflagration venting. Steel frame construction, with light, nonbearing exterior walls and a light roof, is preferable.

A.23.9.3.2.2.1 An appropriate test method is ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*.

A.23.9.3.2.2.2 An appropriate test method is in accordance with NFPA 252.

A.23.9.3.2.3.5 It is recommended that an emergency escape-way for personnel be provided independently.

A.23.9.4.3.3.2 The exclusion of explosion isolation on branch ducts from individual pieces of equipment or interconnected equipment addresses the propagation from the equipment through the ductwork and to the other interconnected equipment (or between portions of the single piece of equipment). It does not address any required explosion isolation on the process flow streams between those pieces of equipment. This exclusion does not apply to the requirements for explosion isolation to protect those pieces of equipment from a deflagration in the AMS, propagating upstream through the dust collection ductwork.

Most dust collection systems operate with sufficient airflow to keep the environment within the connected equipment below the MEC, thereby reducing the risk of explosion originating in those pieces of equipment.

Figure A.23.9.4.3.3.2 is an illustration of a manifolded system with isolation of a branch duct.

A.23.9.4.10.2 It is not the intent of this requirement to prohibit interim storage of bags, drums, or filled containers.

A.23.9.4.14.2 This restriction is not intended to preclude the use of any or all aluminum components, but it should be understood to apply to components in relative motion with each other. The reaction of a metal with the oxide of a different metal is called a thermite reaction. The reactants provide their own oxygen supply and thus present a high fire risk. An example of this is the reaction of aluminum with ferric oxide (rust), where the products would be aluminum oxide and free elemental iron. The rubbing of aluminum metal buckets against a rusted surface will first commingle the aluminum with the ferric oxide and with continued rubbing generate sufficient heat to initiate the reaction and provide an ignition source for the combustible dust in the bucket elevator. For more information, see Hawley's, *Condensed Chemical Dictionary*.

A.23.9.4.15.1 Screw conveyors and conveyors in general can be used for applications other than explosion isolation.

A.23.9.4.19.1.2 Auxiliary instrumentation should be provided for sampling and recording the quality of the inert atmosphere in other parts of the system.

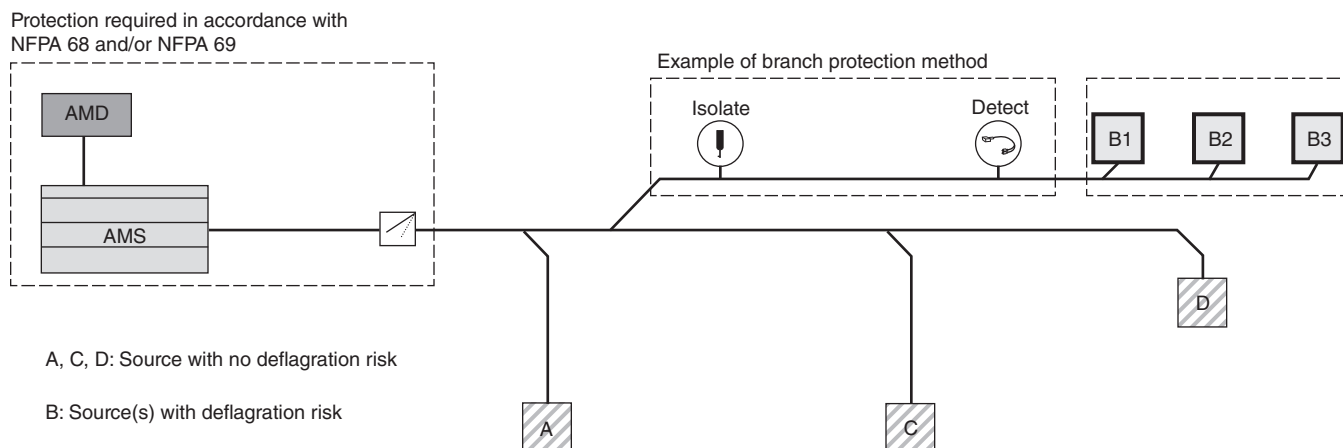


FIGURE A.23.9.4.3.3.2 Manifolded System with Isolation of a Branch Duct.

A.23.9.4.19.4 The large volumes and high velocities of air and the compactness of the attrition-style size reduction equipment make inerting usually impractical.

A.23.9.4.19.4(2) Flooding with inert gas or steam, combined with delayed opening to permit smothering of any residual fire, is recommended.

A.23.9.5.1 It is recommended that the interior of size reduction and packaging rooms or buildings be painted a color that contrasts with the color of the dust.

A.23.9.6.6 See NFPA 77 for information on the subject.

A.23.9.6.6.4 For further information regarding the hazards and uses of flexible and rigid intermediate bulk containers, see Section 9.1 of NFPA 77 and *Avoiding Static Ignition Hazards in Chemical Operations*, pp. 199–204.

A.23.9.6.6.4.2 Unless intentionally removed by the process, sulfur typically contains adsorbed hydrogen sulfide. Dispensing generates static charge, which can ignite not only the combustible dust atmosphere but also the hydrogen sulfide. Minimum ignition energy (MIE) of less than 1 mJ has been reported for particulate sulfur, while MIE of 0.068 mJ has been reported for hydrogen sulfide. MIEs are measured in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*.

A.23.9.6.6.4.2(2) Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers' Type C FIBCs in the presence of hydrogen sulfide atmospheres should be determined. Failure to provide grounding for a Type C FIBC can create a potential static discharge hazard greater than using Type A or Type B FIBCs.

A.23.9.6.6.4.2(3) Due to the particularly low MIE of hydrogen sulfide, the suitability of specific manufacturers' Type D FIBCs in the presence of hydrogen sulfide atmospheres should be determined.

A.23.9.6.6.4.2(4) The use of Type A or Type B FIBCs and insulating RIBCs should be based on a documented risk assessment acceptable to the authority having jurisdiction. Type A and Type B FIBCs and insulating RIBCs can generate sufficient electrostatic energy discharge to ignite ground or crushed sulfur powder (i.e., powders with MIE values = 3 mJ). Dry sulfur can be delivered as formed sulfur (prills, flakes, granules, and

pastilles) as well as powders. Attrition through normal handling could produce fines. Larger forms of sulfur generally would be expected to have higher MIE values, which should be determined by test in accordance with ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, or similar international protocol, and might allow the use of Type A or Type B FIBCs and insulating RIBCs. The determination of the suitability of Type A or Type B FIBCs and insulating RIBCs should be based not only on MIE but also on electrostatic properties, such as electrostatic chargeability and volume resistivity tested in general accordance with ASTM D257, *Standard Test Methods for DC Resistance or Conductance of Insulating Materials*, and MEC tested in accordance with ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*, or similar international protocol. The evaluation should also consider sulfur-handling and sulfur-processing operations prior to FIBC filling and unloading. Generally speaking, faster filling and unloading rates (such as with pneumatic conveying) would be expected to generate higher levels of static charge and should be avoided. If fines with MIE = 3 mJ are present in sufficient quantity to form a suspended dust cloud of sufficient concentration to support a deflagration, as determined in accordance with ASTM E1515 [typically 0.035 oz/ft³ (35 g/m³)], then there is sufficient risk to preclude the use of Type A or Type B FIBCs and insulating RIBCs.

A.23.9.6.6.4.3 Certain fabrics that pose significantly less risk of ignition in flammable atmospheres have been developed for use in FIBCs. One such fabric that has been tested for use in flammable atmospheres and has been used in FIBCs is documented in Ebadat and Mulligan, "Testing the Suitability of FIBCs for Use in Flammable Atmospheres."

A.23.9.6.11.2 It should be recognized that magnetic separators will not remove nonferrous tramp material, including stones, brick, and concrete. Every care, using other means, should be taken to ensure excluding such materials from the size reduction system.

A.23.9.6.14 Although sulfur is not now included in atmospheres classified as Class II, Group G, it has been the experience of the sulfur industry that such equipment can be suitable. However, consideration should be given to the melting point of sulfur, 233°F to 246°F (112°C to 119°C), in the selection of heat-producing electrical equipment.

A.23.9.6.14.2 Refer to NFPA 499. See also Table A.25.9.6.14.2 which provides guidance for area electrical classification.

A.23.9.8.2 Pre-deflagration detection and control systems can be applied where installed in accordance with NFPA 69. However, a pre-deflagration detection and control system should not be used as the primary explosion prevention device. In addition, users are cautioned that infrared or near-infrared detectors are not effective on sulfur fires.

A.23.9.8.3 Methods of explosion protection using containment, venting, and suppression protect the specific process equipment on which they are installed. Flame fronts from a deflagration can propagate through connecting ductwork to other unprotected process equipment and to the building from outside process equipment. Figure A.23.9.8.3(a) shows an example of how this propagation might occur. Isolation techniques as shown in Figure A.23.9.8.3(b) through Figure A.23.9.8.3(e) can be used to prevent the propagation of the deflagration by arresting the flame front.

Both the direction and extent of potential deflagration propagation must be considered. Usually, a dust deflagration occurs in a fuel-rich regime (i.e., above the stoichiometric fuel-air ratio), making it likely that the initial deflagration will expand into volumes that are many times greater than the initial deflagration volume.

The dynamics of a dust explosion are such that unburned dust is pushed ahead of the flame front by the expanding products of combustion. This dust is expelled from the containment vessel via every available exit path, in all possible directions of flow, including flow via all connecting ducts and out through any provided deflagration venting. The driving force pushing the dust away from the point of initiation (which, under vented conditions, might be in the range of a few pounds per square inch) can easily overcome the force of normal system flow (which typically might be of the order of a few inches water column). Furthermore, the velocities produced by the deflagration usually greatly exceed those of the pneumatic conveying system under normal design conditions. Consequently, unburned dust and the deflagration flame front can be expected to propagate upstream through ductwork from the locus of the initial deflagration.

The conveyance of the flame front via both the in-feed and outflow ducts should be evaluated. In most cases, this movement of dust and propagating flame front will commute the deflagration to the connected equipment via ductwork. Where equipment and ducts are adequately protected pursuant to Chapter 23 and NFPA 68 (where deflagration venting is used), the consequences of explosion propagation might not increase the life safety hazard or significantly increase the property damage. However, in other cases, the transit of a deflagration flame front does result in substantial increases in the severity of an event.

In the case of several pieces of equipment connected via ductwork, where each piece of equipment and the ductwork are provided with deflagration venting, the dust explosion can nevertheless propagate throughout the system. Deflagration venting on the equipment of deflagration origin will prevent overpressure damage to that vessel. If the concentration within the connecting ductwork is below the minimum explosible concentration (MEC) prior to the deflagration, the deflagration can still spread to the next vessel, but the deflagration venting there should protect that second vessel from overpres-

sure damage. In such a case, the provision of explosion isolation would not provide any significant reduction in either the property damage or life safety hazard.

If the concentration within a connecting duct is above the MEC prior to the deflagration, then the propagation through that duct will result in an accelerating flame front. Without deflagration venting on the ductwork, this accelerating flame front will result in a significant prepressurization of the equipment at the other end of the duct and in a very powerful jet flame ignition of a dust deflagration within that second vessel. Such a deflagration can overwhelm the deflagration venting on that vessel, even if the design is based on information in NFPA 68, resulting in the catastrophic rupture of the vessel. In this case, the explosion propagation results in a significant increase in the property damage and, quite possibly, in an increase in life safety hazard due to the vessel rupture. Consequently, explosion isolation is a critical component to the management of the fire and explosion risk.

In the case of an AMS serving a large number of storage silos, an explosion originating in the AMS can produce an acceptable level of damage to the collector if it is provided with adequate deflagration venting per NFPA 68. However, the propagation of that explosion upstream to all the connected silos could cause ignition of the material stored in all those silos. The initiation of such storage fires can significantly escalate the magnitude of the incident, in terms of property damage, interruption to operations, and life safety hazard. As with the previous example of a connecting duct having a concentration above the MEC prior to deflagration, explosion isolation would be warranted in this case.

When rotary valves are installed in both the inlet and outlet of equipment, care should be taken to ensure that the rotary valve on the inlet is stopped before the unit becomes overfilled. See Figure A.23.9.8.3(b) for an example of rotary valves.

Figure A.23.9.8.3(c) illustrates one example of deflagration propagation using mechanical isolation.

Figure A.23.9.8.3(d) illustrates one example of deflagration propagation using flame front diversion.

Figure A.23.9.8.3(e) illustrates one example of deflagration propagation using chemical isolation.

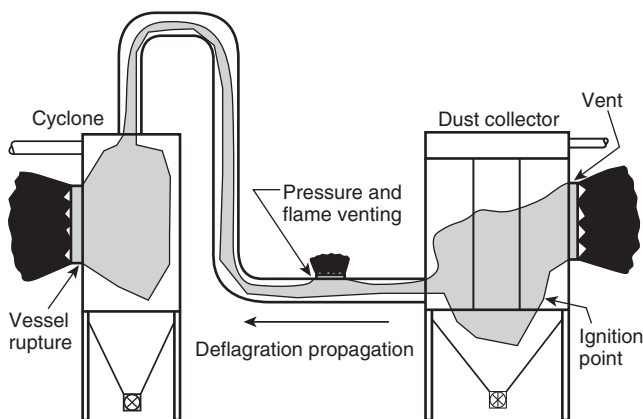


FIGURE A.23.9.8.3(a) An Example of Deflagration Propagation Without Isolation.

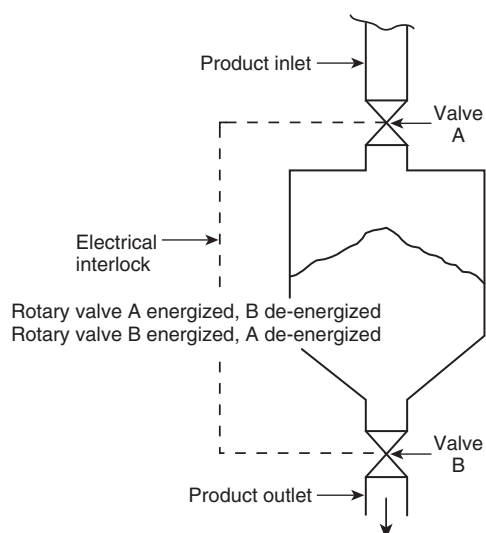


FIGURE A.23.9.8.3(b) Rotary Valves.

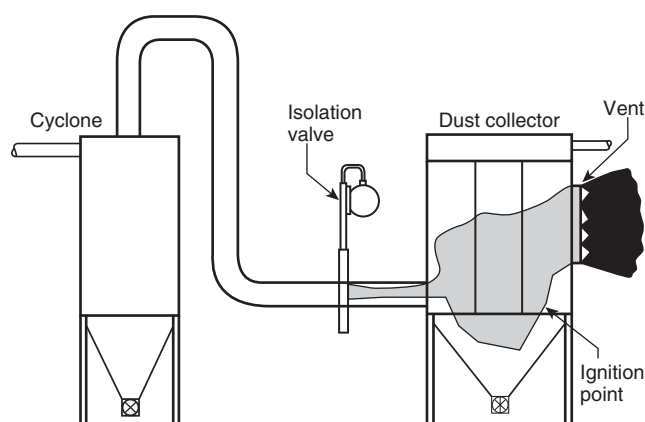


FIGURE A.23.9.8.3(c) Deflagration Propagation Using Mechanical Isolation.

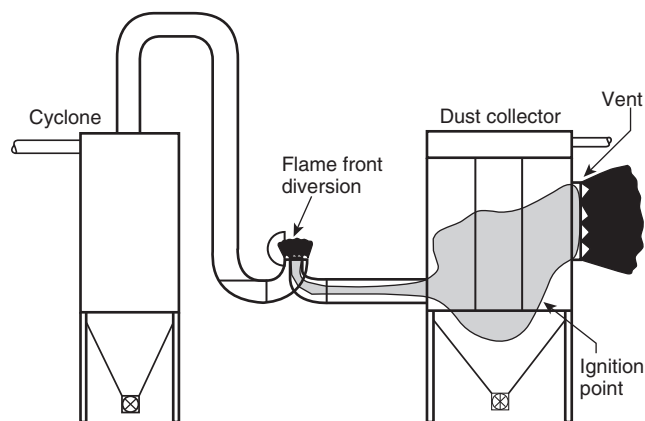


FIGURE A.23.9.8.3(d) Deflagration Propagation Using Flame Front Diversion.

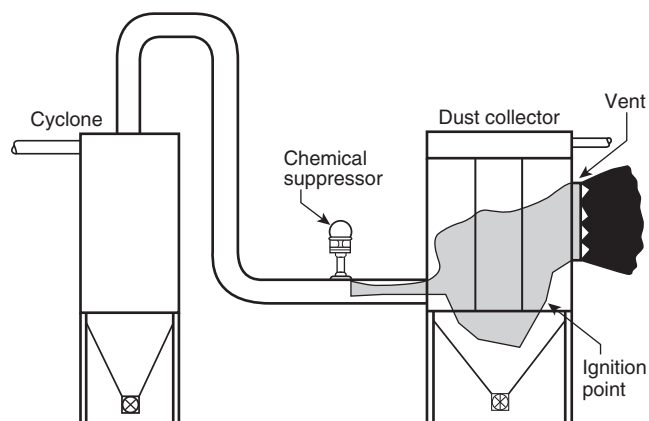


FIGURE A.23.9.8.3(e) Deflagration Propagation Using Chemical Isolation.

A.23.9.8.3.2 Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations, in which the discharge of a fireball from the pickup point would endanger personnel.

A common example for the application of such isolation would be in the upstream duct work associated with a dust collection system servicing a work area. Loading chutes less than 10 ft (3 m) in length and designed for gravity flow are not considered duct work. Due to a high likelihood of ignition of sulfur dust, AMSs should be operated under inert atmosphere.

A.23.9.9.1.2 If a container is tightly closed and the volume of oxygen enclosed is not too large, a fire will be smothered by the sulfur dioxide formed. When steam is used for fire suppression in enclosed equipment, the rate of application should be at least 2.5 lb/min/100 ft³ (1.13 kg/min/2.83 m³).

A.23.9.9.1.4 A period of at least 15 minutes should elapse between closing the valves or gates and opening the equipment to smother any residual fire in the equipment. As an added precaution, the equipment should be flooded with inert gas or steam, if available, prior to opening.

A.23.9.9.4.2 Where a straight stream must be used to reach fires in inaccessible locations, the stream should be directed above the burning material so that the water rains down on the material.

A.23.11.1 The normal handling temperature of liquid sulfur is 250°F to 309°F (121°C to 154°C), which is slightly above the melting point of 246°F (119°C). At the melting point sulfur is a transparent, mobile liquid. As the temperature of the liquid is raised, it darkens, becoming deep orange in hue. Up to about 320°F (160°C) the viscosity drops with rising temperature. Above this point the viscosity increases with rising temperature. At 370°F (188°C) the viscosity reaches a tremendously high maximum that practically prevents it from flowing and the liquid is so intensely colored as to be nearly opaque. Above 370°F (188°C) it again acts in a more normal fashion, with its viscosity falling somewhat as the temperature continues to rise.

At the normal handling temperature of liquid sulfur [250°F to 309°F (121°C to 154°C)] the vapor concentration above the pure sulfur, free of hydrocarbons or hydrogen sulfide, is too low to form a flammable mixture in air. While the flash point of liquid sulfur varies with purity, it is always higher than the

normal handling temperature. For pure sulfur, the flash point can be as low as 370°F (188°C) and for relatively impure crude sulfur, the flash point can be as low as 334°F (168°C).

The relative low ignition temperature of sulfur and the possible presence of hydrogen sulfide are the primary fire and explosion hazards of liquid sulfur. Impure sulfur (sometimes referred to as “dark sulfur”) contains hydrocarbons, which react slowly with the liquid sulfur to form hydrogen sulfide. Recovered sulfur, such as that produced from petroleum gas streams containing the hydrogen sulfide using the Claus Process, often contain dissolved hydrogen sulfide, which will be liberated slowly from a quiescent body of liquid sulfur. Agitation of such liquid sulfur will cause rapid evolution of hydrogen sulfide, which can create a flammable atmosphere within the storage tank. In the temperature range at which the liquid sulfur is normally handled, the lower flammable limit for hydrogen sulfide is at about 3.4 percent compared to 4.3 percent at room temperature.

Pure sulfur will not generate a flammable atmosphere in the normal temperature range of the liquid. Transfer of liquid sulfur using air pressure should be avoided. If air pressure is applied to the vapor space of an enclosure containing molten sulfur with high concentrations of hydrogen sulfide, there is a danger that the hydrogen sulfide/air mixture will become flammable. Transfer by pressure should be restricted to using an inert gas. Use of pumps would be the preferred transfer method.

Because impurities can cause generation of H₂S or pyrophoric iron sulfides, testing a representative sample of incoming batches for carbon content and hydrogen sulfide should be performed. These impurities should be kept to a minimum.

A.23.11.2.1 The sensing elements of some explosimeters are not designed for and are adversely affected by hydrogen sulfide-containing atmospheres.

A.23.11.3.3 See NFPA 77 for information on the subject.

A.23.11.3.4 Pyrophoric iron sulfide compounds can form from impurities in the sulfur. When heating coils are exposed to air, ignition can occur.

A.23.11.3.5 Due to the potential for release of dissolved hydrogen sulfide, molten sulfur handling systems require a Class I, Group C, classification for confined areas.

A.23.11.5.1(2) The steam should preferably be introduced near the surface of the molten sulfur. See NFPA 86, Section F.3.

A.23.11.5.1(3) For enclosed sulfur tanks or sulfur pits with air sweep systems designed to meet the requirements of NFPA 69, the sealing steam should be fed into the enclosure very near the air inlets. For such sulfur tanks and sulfur pits the use of a steam rate of 1.0 lb/min (0.45 kg/min) of steam per 100 ft³ (2.83 m³) of total tank or pit volume is expected to develop a positive pressure in the enclosure, thereby sealing the sulfur tank or sulfur pit and preventing air ingress and extinguishing the fire.

As the sealing steam vents backwards through the air inlets the sealing steam will quickly stop air ingress to the fire. Sealing steam should be fed into the sulfur tank or sulfur pit for a minimum of 15 minutes or until the temperature has returned to near normal. For further information and good engineering

practice regarding sealing steam, see Mosher et al., *Molten Sulfur Fire Sealing Steam Requirements*.

A.24.1.1.2 Specific criteria in this standard are advisable for facilities that fall outside this document's scope. A hazard and risk analysis should be performed to identify areas where specific criteria are appropriate. For small installations, simplified versions of some of the management systems might be appropriate.

A.24.5.2.3 For example, the material coming from a hog or a planer through a duct can be considered a uniform mixture during the conveying process; however, material entering a silo, storage vessel, or other enclosure will separate, with the fines occupying the ullage space and creating a potential deflagration hazard.

A.24.5.2.4 In addition to excessive particle size, there are other reasons why a test sample cannot be tested, such as insufficient material or agglomeration issues, which would not necessarily mean the particulate is nondeflagrable.

A.24.7 A process analysis is a methodical review of the facility, each operation housed within, and the identification of where a hazard exists. For example, in a woodworking facility it would include where fire hazards exist, where explosion hazards exist, and what protective measures are in place to protect the personnel and property from those hazards. For additional information, see Chapter 7.

A.24.7.3.4.1 NFPA 664 used a layer depth of 1/8 in. (3.2 mm) for many years as the criterion for determining where a deflagration hazard exists due to the accumulation of deflagrable wood dust. The loss history in the forest products industries does not include events of building compartment deflagrations (i.e., flash fires) where dust layers are as low as 1/8 in. (3.2 mm) in thickness. The losses have been in facilities where dust accumulations are far greater. Therefore, the 1/8 in. (3.2 mm) criterion appears to have a substantial margin of safety.

In previous editions of NFPA 664 there was advisory text in the annex that recommended 1000 ft² (93 m²) or 5 percent of the floor area limitation be considered when determining where a building compartment deflagration hazard exists. This recommendation is based on calculations, not loss history. In the last edition, those recommendations were moved to the body of the standard. With this edition, the recommendations have returned to this annex.

Where a large building compartment is involved 1/8 in. (3.2 mm) of dust distributed evenly over the entire area can result in a substantial quantity of dust. If that quantity is all ignited a serious deflagration will result. But this conclusion is reliant upon a number of simplifying assumptions in calculations used to support such a prediction. The lack of loss history with dust accumulations at the 1/8 in. (3.2 mm) thickness level suggests that some of those simplifying assumptions might not be valid. To date no research has been done that provides advice on how valid those simplifying assumptions actually are. Because designating a building compartment a deflagration hazard places significant limitations on how processes are operated in such an environment, the technical committee has concluded that there must be a solid technical basis for making the area limitation an enforceable part of the standard. At this time that basis does not exist.

A relatively small initial dust explosion will disturb, and suspend in air, dust that has been allowed to accumulate on the

flat surfaces of a building or equipment. This dust cloud provides fuel for a secondary explosion, which usually causes the majority of the damage. Therefore, recognizing and reducing dust accumulations is, a major factor in reducing the hazard in areas where a dust hazard can exist. Prudent operating policies would advise evaluating dust levels wherever a visible dust cloud exists. Where dust accumulations are identified, an engineering analysis should be performed to determine whether a deflagration hazard exists.

Using a bulk density of 20 lb/ft³ (320 kg/m³) and an assumed concentration of 0.35 oz/ft³ (350 g/m³), it has been calculated that a dust layer that averages 1/8 in. (3.2 mm) thick covering the floor of a building is sufficient to produce a uniform dust cloud of optimum concentration, 10 ft (3 m) high, throughout the building. This situation is idealized, and several factors should be considered.

First, the layer will rarely be uniform or cover all surfaces, and second, the layer of dust will probably not be completely dispersed by the turbulence of the pressure wave from the initial explosion. However, if only 50 percent of the 1/8 in. (3.2 mm) thick layer is suspended, this material is still sufficient to create an atmosphere within the explosive range of most dusts.

Consideration should be given to the proportion of the building volume that could be filled with a combustible dust concentration. The percentage of floor area covered can be used as a measure of the hazard. For example, a 10 ft × 10 ft (3 m × 3 m) room with a 1/8 in. (3.2 mm) layer of dust on the floor is a hazard and should be cleaned. Now consider this same 100 ft² (9.3 m²) area in a 2015 ft² (188 m²) building — this is also a moderate hazard. This area represents about 5 percent of a floor area and is about as much coverage as should be allowed in any plant.

To gain proper perspective, the overhead beams and ledges should also be considered. Rough calculations show that the available surface of the bar joist is about 5 percent of the floor area. For steel beams, the equivalent surface area can be as high as 10 percent.

Based on this information, the following guidelines have been established:

- (1) Dust layers 1/8 in. (3.2 mm) thick can be sufficient to warrant immediate cleaning of the area.
- (2) This dust layer is capable of creating a hazardous condition if it exceeds 5 percent of the building area.
- (3) Dust accumulation on overhead beams and joists contributes significantly to the secondary dust cloud and is approximately equivalent to 5 percent of the floor area. Other surfaces, such as the tops of ducts and large equipment, can also contribute significantly to the dust cloud potential.
- (4) The 5 percent factor should not be used if the floor area exceeds 20,000 ft² (1858 m²). In such cases, a 1000 ft² (93 m²) layer of dust is the upper limit.
- (5) Due consideration should be given to dust that adheres to walls, because this is easily dislodged.
- (6) Attention and consideration should also be given to other projections, such as light fixtures, which can provide surfaces for dust accumulation.
- (7) Dust collection equipment should be monitored to be certain it is operating effectively. For example, dust collectors using bags operate more efficiently between limited

pressure drops of 3 in. to 5 in. (0.75 kPa to 1.24 kPa) of water. An excessive decrease or low drop in pressure indicates coating that is insufficient to trap dust.

These guidelines will serve to establish a cleaning frequency.

A.24.7.3.4.3 In some cases, such as fine particulates generated from hardwoods, it is advisable to correct for a settled bulk density in excess of the 20 lb/ft³ (320 kg/m³), used in this requirement.

The measurement of bulk density is very dependent upon the particle, size, shape, and chemical content. Settled bulk density is not the same as tapped bulk density. Settled bulk density is the density as the material has settled in the facility under normal operating conditions. Tapped bulk density is the maximum density that can be achieved without intentional compression. Tapped bulk density measurement numbers are almost always higher than settled bulk density measurement numbers.

Moisture content is a factor that has a profound effect on dust deflagration propagation. Moisture in dust particles raises the minimum ignition temperature (MIT), minimum ignition energy (MIE), and minimum explosible concentration (MEC) by increasing agglomeration of particles.

Moisture content can be determined using the following method:

- (1) Weigh the material of which a moisture content is to be determined in the moist, as-received state.
- (2) Then dry it for 24 hours in a drying oven set at 167°F (75°C).
- (3) Then reweigh the sample.

Calculate the moisture content from the following relation:

[A.24.7.3.4.3]

$$\%MC = \frac{[(\text{moist weight}) - (\text{dry weight})](100)}{\text{moist weight}}$$

While no ASTM method currently exists for determining settled bulk density, the following method has been utilized to produce usable results. Since the use of bulk density measurements is to determine the permissible dust layer depth for hazard assessment, bulk density should be based upon the dried weight, not moist weight; the water in the moist sample does not add combustible material to the mixture.

Recommended Tools: Neoprene or other similar plastic-type gloves, ruler, two natural bristle brushes [4 in. (100 mm) width], scales (that measure grams), pre-weighed container (weighed in grams to nearest tenth of a gram), and a drying oven.

Recommended Procedure:

- (1) Pre-weigh and record container weight.
- (2) Locate horizontal surface area where dust is present and is evenly distributed across a flat surface. This is an important criterion.
- (3) Mark off a 1 ft² (0.09 m²) area. (It is easier if one of the four sides is the horizontal surface ledge). If one square foot is not available due to size of surface use: 1/2 ft × 2 ft; 1/4 ft × 4 ft, etc.
- (4) Using the ruler as a guide, carefully scrape the other dust surrounding the marked 1 ft² (0.09 m²) (or other established one square foot dimension) back away from

the dust square (or rectangle) to at least 8–12 in. Use the first brush if needed to clean dust away from the 1 ft² (0.09 m²) selected for density measurement [ensuring that the 1 ft² (0.09 m²) area does not receive any of the dust being brushed away].

- (5) Measure and record the height (to the nearest $\frac{1}{32}$ in.) of the dust layer as it sits on the horizontal layer. Take a minimum of three to five measurements along the edge of the dust layer to establish an average height (to the nearest $\frac{1}{32}$ in.) of the dust layer.
- (6) Take the second clean, natural bristle brush and carefully brush the dust contained inside the 1 ft² (0.09 m²) area into the pre-weighed container.
- (7) At this time, the dust sample must be dried as outlined above.
- (8) Weigh the dried dust sample and the container together and record the weight in grams.
- (9) Subtract the weight of the container from the weight of the dried dust-filled container to obtain the weight of the dried dust in grams. Record the dust weight.
- (10) Calculate volume of the dust layer using average height measured (in inches) $\times$ length (12 in.) $\times$ height (12 in.) to obtain cubic inches of volume.
- (11) Convert cubic inches to cubic feet.
- (12) Convert grams of dust measured to pounds. (Note: 453.6 g = 1 lb).
- (13) Divide pounds of dust by cubic feet to establish estimated density in pound per cubic feet (lb/ft³).

Example:

Container pre-weight is 500 g.

Average dust height measured is $2\frac{1}{32}$ in.

Container plus dust weight is 660 g.

Dust Volume Determination in cubic feet (ft³):

$2\frac{1}{32}$ in. = $\frac{65}{32}$ in., or 2.03125 in. (51.6 mm)

Volume (in.³) = L $\times$ W $\times$ H = 12 in. $\times$ 12 in. $\times$ 2.03125 in. = 292.5 in.³

Convert cubic inches to cubic feet: There are 1728 in.³ in 1 ft³.

Volume (ft³) = Volume (in.³) $\div$ 1728 = 292.5 $\div$ 1728 = 0.169 ft³ (0.0048 m³)

(305 mm $\times$ 305 mm $\times$ 51.6 mm) = (0.305 m $\times$ 0.305 m $\times$ 0.0516 m = 0.0048 m³)

Dust Weight Determination in pounds (lb):

To obtain the weight of the dust, subtract container weight in grams from weight of the container containing the dried sample:

660 g – 500 g = 160 g

Convert grams to pounds. There are 453.6 g in 1 lb, therefore:

160 g $\div$ 453.6 g/lb = 0.353 lb (of dust)

Dust Density Determination:

Divide pounds of dust by volume of dust in cubic feet:

0.353 lb $\div$ 0.169 ft³ = 2.087 lb/ft³.

Round off to nearest tenth of a pound = 2.1 lb/ft³

[0.16 kg $\div$ 0.0048 m³] (33.43 kg/m³).

A.24.8.4.1.1 These materials include, but are not limited to, bark, chips, scrap lumber, wood dust, and other debris within wood processing and woodworking facilities.

A.24.8.4.1.2 Examples of energized or moving equipment include, but are not limited to, transformers, switches, buses, conveyor rollers or drums, motors, mechanical drive equipment, steam lines, heated air transfer ducts, and thermal oil lines.

A.24.8.4.1.5 It is always preferable and inherently safer to prevent the escape of dust through the provision of a properly designed, operated, and maintained dust collection system than it is to clean up dust that has escaped due to leaks and other deficiencies of the dust collection system.

A.24.8.4.1.6 Temporary control measures for leaks include drip pans or approved absorptive materials. These measures should not be used as an alternative to regular preventive maintenance. Consideration should be given to the use of fire-resistant hydraulic fluids to reduce the fire hazards of hydraulic systems in plant process equipment.

A.24.8.4.2.1 The facility should implement a weekly housekeeping inspection in the facility's fire prevention and maintenance program. Cleaning schedules for production equipment and the facility in general can be based on the findings of the housekeeping inspection. Typical cleanup routines, as a minimum, should include the following:

- (1) Daily, or per shift, cleanup of personal work areas, walkways, emergency escape routes, and accessways to fire protection equipment.
- (2) Weekly cleanup of floors throughout the facility, and specific cleanup in and around materials-handling equipment or production equipment (e.g., beneath lumber sorting decks, beneath or at the transfer points of belted chip or scrap conveyors, and beneath board presses). Machinery, motors, and hot surfaces should be kept clean of materials such as sawdust, oil, or grease.
- (3) Weekly to semi-annual cleanup of dust collection on horizontal surfaces (e.g., ducts, hoods, interior mezzanines, or ceilings) and on structural building members, such as ledges, beams, and joists, to minimize dust accumulations. As a rule of thumb, do not exceed $\frac{1}{8}$ in. (3.2 mm) in depth. In all cases, consideration should be given to minimizing horizontal surfaces where dust can accumulate. One method of reducing horizontal surfaces on structural building members is to install angled members (angle of repose) or shields to minimize buildup.

A.24.8.4.2.6 Sweeping and/or vacuuming are the preferred methods to be utilized. Blowing down with steam or compressed air, or even vigorous sweeping, produces dust clouds. Facilities should not be operating during blowdown. Blowdown should be done in individual sections of the building, starting near the center and working out, to prevent filling the entire building with dust-laden air. Blowdown should be frequent enough that large amounts of dust are not blown into suspension.

A.24.8.4.2.6.1 All of the listed precautions in 8.4.2.6.2 might not be required for limited use of compressed air for cleaning minor accumulations of dust from machines or other surfaces between shifts.

A.24.8.7.3 In addition to inspecting the fire and explosion protection systems that could be in place, such a program should include, but not be limited to, inspections of dust collection system components, electrical transformers, switchgear and switches, large motors (e.g., greater than 200 hp), hydraulic and lubricating systems, rotating machinery (e.g., debarkers, chippers, mills, refiners, dryers, and roll presses), and deficiencies with electrical devices (e.g., arcing, lighting, and damaged wiring) in and around dust-producing processes. Arcing switches, worn bearings, worn belts, damaged wiring, and misaligned parts, including gears, pulleys, guards, and fairings, have all been identified as being sources of ignition.

A.24.8.7.4.1 Recommended inspection items include, but are not limited to, the following:

- (1) Fans and blowers should be checked for excessive heat and vibration pursuant to manufacturer's recommendations.
- (2) The surfaces of fan housings and other interior components should be maintained free of rust (iron oxide). Such rust can become dislodged and, while transported, strike against the duct walls. In some cases this can cause an ignition of combustibles within the duct.
- (3) The interior sections of the collection system (e.g., ducts, fan housings, collectors) should be inspected and cleaned frequently enough to prevent accumulation within the system. Combustible deposits thicker than $\frac{1}{8}$ in. (3.2 mm) should be removed. The method of cleaning will vary with the nature of the deposits. Lint and dust can be removed with brushes. Soft, gummy deposits are commonly scraped with safety tools. Where the deposits are exceptionally hard, it can be necessary to melt them with steam. Open flames should not be used.
- (4) Abort gates and abort dampers should be adjusted and lubricated pursuant to manufacturer's recommendations.

A.24.8.7.4.2 The use of aluminum paint makes the fire hazard worse. If the aluminum flakes off or is struck by a foreign object, the heat of impact could be sufficient to cause ignition of the aluminum particle, thereby initiating a fire.

A.24.8.7.5.1 Impairments can include isolating of fire pump controllers, closing of sprinkler system control valves, and isolating and disabling or disconnecting of detection and suppression systems.

A.24.8.7.5.2 The impairment procedure consists of identifying the impaired system and alerting plant personnel that the protection system is out of service.

A.24.8.7.5.3 The facility manager is responsible for ensuring that the condition causing the impairment is promptly corrected.

A.24.8.7.5.4 When the impairment notification procedure is used, it triggers followup by the relevant authorities having jurisdiction. This followup helps to ensure that impaired fire and explosion protection systems are not forgotten. When the system is closed and reopened, most companies notify their insurance company, broker, or authority having jurisdiction by telephone or other predetermined method.

A.24.8.8.1 Employees' health and safety in operations depend on recognizing actual or potential hazards, controlling or eliminating these hazards, and training employees to work safely.

A.24.8.8.3(1) An important part of preventive maintenance is employee training in the proper care and use of equipment. Employees should be given instructions in selecting the proper tool for the job and the limitations of the tool. Training in operating and maintenance procedures and emergency plans should be developed. A training program appropriate to the types and quantities of hazardous materials stored or used should be conducted to prepare employees to handle hazardous materials safely on a daily basis and during emergencies. This training program should include the following:

- (1) Identification of all hazardous materials present and specific hazards of these materials
- (2) Instructions in safe storage and handling of hazardous materials, including maintenance of monitoring records
- (3) Instructions in emergency procedures for leaks, spills, fires, or explosions, including shutdown of operations and evacuation procedures

A.24.8.8.4 Such persons should also be familiar with the proper use of special precautionary techniques, personal protective equipment, lockout/tagout requirements, insulating and shielding materials, and test equipment. A person can be considered qualified with respect to certain equipment and methods but still be unqualified for others.

Employees should be trained to recognize obvious defects or malfunctioning equipment within their work area. Such defects should be reported immediately.

A.24.8.8.6 Training should also be given to new employees when they join a company and to company employees transferring to a new department or location.

In addition to the requirements in 24.8.8, employee training should comply with the following standards, as applicable:

- (1) NFPA 1
- (2) NFPA 10
- (3) NFPA 25
- (4) NFPA 30
- (5) NFPA 49 (Incorporated into the NFPA *Fire Protection Guide to Hazardous Materials*)
- (6) NFPA 55
- (7) NFPA 68
- (8) NFPA 69
- (9) NFPA 70
- (10) NFPA 72
- (11) NFPA 80
- (12) NFPA 85
- (13) NFPA 600

Note that although NFPA 49 has been officially withdrawn from the *National Fire Codes*®, the information is still available in NFPA's *Fire Protection Guide to Hazardous Materials*.

A.24.8.10 The size and extent of the incident that triggers an investigation should be proportional to the hazard. For example, a spark in a protected duct with a spark detection system would likely not require an investigation unless a significant increase in sparks per unit time was noted or the spark fails to be extinguished. This incident is considered "recorded" with the spark detection system. For every hazard area, there is a de minimis level below which recording cannot be justified. It is up to the owner/operator to determine that level.

A.24.8.11 Management of change should be applied to more than just new construction projects. Management of change encompasses anything that could adversely impact loss potentials, including physical and human element changes, whether at the site, in the corporation, in the industry, or in the community.

It is critical that changes be evaluated early enough to easily accommodate all loss prevention objectives. Opportunities to enhance fire safety should be investigated during the management-of-change process.

A.24.8.11.2 Modifications to existing programs, equipment, or personnel should include review of the original design parameters to ensure that they have not been compromised.

A.24.8.11.2(1) Often, changes to the occupancy and process precipitate the need to change the fire protection strategy employed for that process or occupancy.

A.24.8.11.2(2) Changes to fire protection and alarm systems can include, but not be limited to, automatic sprinkler protection, special protection systems, water supplies, and alarm equipment.

A.24.8.11.2(3) Exposure changes include yard storage and changes to neighboring facilities.

A.24.8.13.1 The following standards have explicit requirements for record retention:

- (1) NFPA 10
- (2) NFPA 13
- (3) NFPA 20
- (4) NFPA 24
- (5) NFPA 25
- (6) NFPA 68
- (7) NFPA 69
- (8) NFPA 70
- (9) NFPA 72
- (10) NFPA 80

A.24.8.13.2 For record retention to be useful, the minimum acceptable documentation should identify what was tested/inspected, and when and whether it performed successfully. Corrective action taken should be noted on or maintained with the inspection/testing record.

A.24.8.13.3 At a minimum, records should be retained until subsequent inspection or testing has superseded them. Consideration should be given to identifying and maintaining records that can serve as predictive maintenance tools. Original records, such as manufacturers' data sheets, as-built drawings, or contractor test certificates, should be retained for the life of the equipment.

A.24.8.13.4 Permissible media for records can include written, printed, or computer-generated documents, drawings, or photographs.

A.24.8.13.5 Files, inspection reports, investigations, training programs, and related documents should be maintained in compliance with the recordkeeping policies of the organization so that information can be easily retrieved.

Computer programs that file inspection and test results should provide a means of comparing current and past results and should indicate the need for corrective maintenance or further testing.

A.24.9.3.1 It is preferable for buildings engaged in wood processing either to be of Type I or II construction or to be sprinklered, or both, if a hazards analysis deems it is warranted.

A.24.9.3.2.1 Refer to NFPA 80A for buildings using open space separation techniques.

A.24.9.3.2.3.3 Penetrations for piping and ductwork used to convey combustible materials should not penetrate fire walls. Fire dampers in ducts handling wood particulates have not been shown to provide reliable operation over the lifetime of the facility. The wood waste often clogs dampers, rendering them inoperative.

A.24.9.3.2.3.5(B) Such doors should be marked "Not An Exit." The unique requirements of doors in explosion-resistant walls preclude their use as a means of egress, because NFPA 101 requires exit doors from high-hazard areas to swing in the direction of exit travel.

A.24.9.3.3.2.1 This provision requires shorter travel distances and wider egress pathways resulting in shorter egress times for those occupancies with high hazard contents. In many cases it requires multiple means of egress so that occupants do not have to travel past a hazardous situation while evacuating the facility.

A.24.9.3.4 Structural steel that is out of the reach of normal vacuuming or sweeping operations and that has horizontal ledges (such as I-beams or U-shaped channels in the up or side-ways position) should be boxed in with a limited-combustible material to eliminate pockets for dust accumulation. New interior walls should be specified as being smooth and with minimal ledges.

Surfaces not readily accessible for cleaning should be inclined at an angle of not less than 45 degrees from the horizontal to minimize dust accumulation.

As much as a 60 degree angle of inclination could be necessary for maximum effectiveness with many types of wood dust. Horizontal surfaces that can benefit from a sloped cover include girders, beams, ledges, and equipment tops.

A.24.9.3.6 See FM Property Loss Prevention Data Sheet 1-44, *Damage-Limiting Construction*, for more information.

A.24.9.3.6.2 See NFPA 68 for guidance on predicting the effects of dust deflagrations based on the strength of resisting and relieving walls.

A.24.9.3.6.3 See NFPA 68 for guidance on the strength of relieving and resisting walls.

A.24.9.4.1.1 These systems include, but are not limited to, dust collection systems and pneumatic bulk conveying systems transporting material from hogs, hammermills, grinders, flakers, planers, refiners, sanders, and chippers.

A.24.9.4.3.1 Assume that all wood waste in an enclosed dust collector is potentially deflagrable, unless a dust deflagration test demonstrates it is not. Wood waste usually has a dust deflagration risk where the mean particle size is less than 500 μm and where as little as 10 percent of the mixture contains dust less than 80 μm in size. Only weak deflagrations are likely where the mean particle size exceeds 500 μm .

Wood waste is commonly produced by the following:

- (1) Fine cutting (e.g., sanding), which produces a dust of very fine particle size. This dust is usually assumed to be deflagrable.
- (2) Machining and sawing softwoods, which produces chips, shavings, and coarse dust with only a small amount of fine dust. This process does not normally create a deflagration risk, so long as the fine dust is not allowed to separate and accumulate within confined spaces.
- (3) Sawing and machining hardwoods, which often produces wood waste containing considerably more dust than that from softwood. This dust is usually assumed to be deflagrable.
- (4) The processing of MDF chipboard and similar boards by machining and sawing. This process can be expected to produce waste containing much fine dust. This dust is usually assumed to be deflagrable.

When mixed processing of a variety of woods occurs, the waste produced should be assumed to be deflagrable.

A.24.9.4.3.1.4 For example, dust collectors having combustible filter bags and rubber belt conveyors would pose a fire hazard, even if only green wood particulate were handled.

A.24.9.4.3.1.5 The hazard threshold used is less than 100 percent to allow for concentration increases that can occur due to system imbalances and minor changes or adjustments to material or airflow rates, and at fans, elbows, hopper feed points, and so forth. For systems that have intermittent operation and/or multiple particulate entry points, the maximum concentration should be based on the simultaneous maximum material flow rate from all entry points. For example, the dust loading for a pneumatic system that collects dust from two panel sanders should be based on the material being removed from panels passing through both sanders at the same time, even if this happens randomly.

A.24.9.4.3.2.1(B) Dust collectors for wood working should be labeled, “For Wood Dust Only — Do not use with metal dust or operations that generate sparks or flammable vapors, to avoid fire and/or explosion.” It is the responsibility of the owner of the dust collector to provide this warning label or a similar one on the dust collector, if the label is not provided by the dust collector manufacturer.

In addition, similar warning labels could be located at wood-working machines.

A.24.9.4.3.2.1(D) While conditions can vary, 4000 ft/min (20 m/sec) is generally accepted as a minimum conveying velocity for wood particulate. Actual capture velocity can be much higher; the manufacturer should be consulted for specific recommendations.

A.24.9.4.3.2.2(C) A ground wire or other grounding system for PVC pipe is not acceptable.

A.24.9.4.3.2.2(I) Where dampers or gates are necessary to achieve balance on systems that have been altered, they should be permanently fastened in place. Dampers should not be opened and closed during operation so that more suction can be diverted to other machines/branches, because the imbalance of airflow can cause insufficient velocity in the main duct, which will result in an accumulation of wood waste and become a potential fuel source for fire.

An automatic damper that is located in a branch duct and dedicated to an individual woodworking machine, and that opens when the machine is activated and closes when the machine is deactivated, should not be used if it will cause insufficient velocity [less than 4000 ft/min (20 m/sec)] in the main duct.

Variable speed controls, whether manual or automatic, should not be used if they can cause insufficient velocity in the main duct.

Sufficient velocity can be achieved by a number of methods, including the following:

- (1) Automatic damper and variable speed controls (if the branch pipe with the damper does not feed into the main duct but goes directly to the dust collector)
- (2) Dampers controlled by programmable controllers
- (3) Other engineered systems that maintain design velocity

A.24.9.4.3.2.2(L) Resinous woods such as southern yellow pine, spruce, and fir tend to yield wood dust that is tacky and can adhere to duct interiors. This is especially true on ducts serving abrasive planers and sanders, which also introduce heat input to the dust.

Hardwoods such as maple, oak, hickory, and cherry lack the resins of the soft woods and are much less likely to coat duct interiors with accumulated dust.

A.24.9.4.3.2.2(M) Ductwork subject to dust accumulation should have sufficient access for inspection and fire department access, as determined by the configuration, length, and size of the duct.

A.24.9.4.3.2.4(A) Although conditions can vary, 4000 ft/min (20 m/sec) is generally accepted as a minimum conveying velocity for wood particulate.

Many believe that fans should be located only on the clean-air side of dust collection equipment because this removes the fan, a potential ignition source, from the dusty airflow. Where deflagrable dusts are being conveyed, turbulence induced by fans can also accelerate deflagration burning, increasing the pressure rise (and damage potential) to the fan and duct in proximity to the fan inlet and outlet. However, the frequency of fans being an ignition source is very low.

Additionally, there is an advantage to having the fan upstream of the collection equipment. The fan can be left running to rapidly purge the duct of any material and discharge it from the system through a fast-acting abort gate. When actuated by a spark detector located a sufficient distance upstream, such an arrangement can effectively keep burning material from entering the dust collection equipment where the fire and explosion potential is known to be extremely high. Although this can also be done with negative pressure systems where the fan is located on the downstream side of the collector, it is a much more complex and expensive solution.

A.24.9.4.3.2.4(B)(1) The clean-air side of the dust collector is the preferred location for the fan or blower. When wood particulates are passed through the fan, there is the potential for ignition of the wood particulate due to the impact of the impeller, frictional heat from the fan motor, and bearings or fan impeller failure. Acceptable means for addressing this ignition potential are dependent upon the moisture content, particle size distribution, and minimum explosible concentration of the fines.

A.24.9.4.3.2.4(B)(2) No experience in the forest products industry is known to the members of the Technical Committee that indicates that an ignition of green wood particulates has occurred in the context of the conveyance systems. However, the user should keep in mind that wood particulates will lose moisture as they are conveyed. Variations in feedstock will also result in variations in the moisture content of the conveyed material. The conveyed material should be sampled at all extremes of operations to verify that the conditions that allow transport without downstream fire protection exist reliably. Furthermore, the wood particulates in such systems should be routinely sampled to ensure that the conveyance system is not operating outside of the design parameters.

A.24.9.4.3.2.4(C) Designing a fan housing that can withstand maximum unvented explosion pressures is generally impractical except for very small fans. Also, the fan wheel or blower impeller acts as an obstruction to deflagration propagation and increases the air turbulence, both of which can increase deflagration pressures. Because of this, explosion suppression systems generally need to inject suppression agent into both the inlet and exhaust openings of the fan housing. Also, deflagration venting might not be practical on the fan housing itself, so vents need to be located on the inlet and outlet ducts as close to the fan housing as practical. The duct vents should have an area equal to the cross-sectional area of the duct.

A.24.9.4.4.4 Item (2) is intended to ensure that nothing becomes a projectile and represents a missile hazard in the event of a deflagration within the filter media. Cloth filter bags, unenclosed cartridge-type felt, or paper filter media are acceptable. Additionally, where wire screen is used to provide mechanical support for the filter media, it is not considered a serious missile hazard. However, a cartridge enclosed within a metal container is not acceptable. Two typical enclosureless dust collectors are shown in Figure A.24.9.4.4.4.

A.24.9.4.4.5 Although alternatives to out-of-doors locations are permitted, allowing indoor locations under special circumstances, outdoor locations are highly recommended. It is not advisable to locate dust collectors on the roofs of buildings.

A.24.9.4.4.5(7) It is good practice to protect an enclosureless dust collector with either an automatic sprinkler located above

the unit or a spark detection and extinguishing system in the main duct, upstream of the unit.

A.24.9.4.4.6.1 It is recommended that a secondary filter, dust particle emission sensor, or combination of both be used as part of the return air duct to prevent dust propagation into the building interior due to primary filter failure. See ACGIH's *Industrial Ventilation — A Manual of Recommended Practice*.

A.24.9.4.4.6.2 The requirement for the return air diversion is in place to protect the occupants from the products of a dust collector fire. This requirement is normally achieved with the use of abort gates that are activated by spark detectors. However, the committee has not achieved consensus regarding the design of this feature.

One approach is to locate the spark detection and abort gate on the inlet duct to the dust collector, which is shown in Figure A.24.9.4.4.6.2(a). With this approach, the burning material is detected by the spark detectors as it travels towards the dust collector. The operation of the spark detectors actuates the abort gate release, diverting the burning material from the dust collector. This prevents the burning material from entering the dust collector and thereby prevents the recirculation of smoke, flame, and other fire products back to the occupied portion of the facility. An additional advantage to this approach is protection of the dust collector.

This approach works best when a fan is located upstream of the dust collector so that the airflow from the fan accelerates the closure of the abort gate. However, fans are often ignition sources and this approach has the disadvantage of initiating comparatively frequent dust collection system shutdowns due to sparks.

The second approach is shown in Figure A.24.9.4.4.6.2(b). In this design the spark detectors and abort gate are located on the clean air side of the dust collector. With this approach the return air diversion relies upon sparks from burning bags and ignited dust flowing through holes in the bags for the stimulus to actuate the abort gate. This approach has the advantage that it does not divert the airflow except under circumstances of an established fire in the dust collector. However, it does not

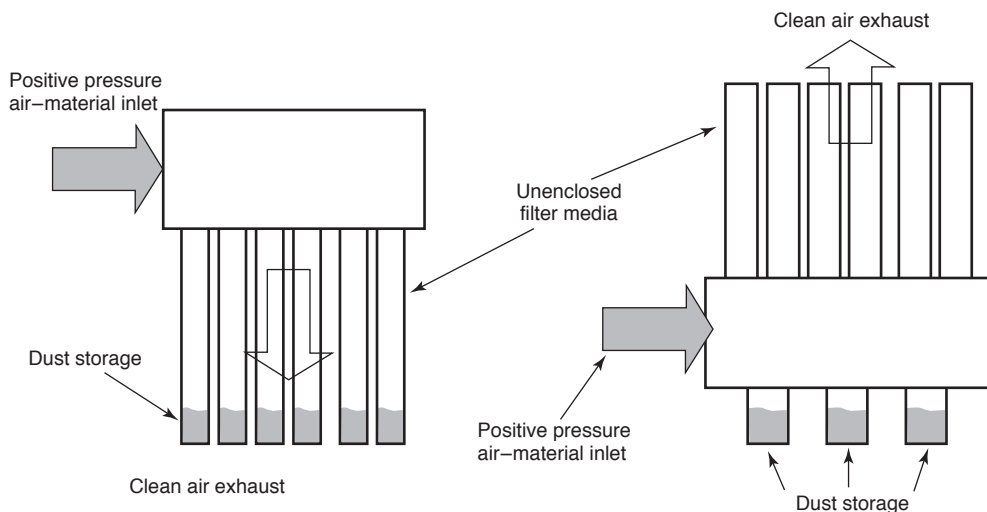


FIGURE A.24.9.4.4.4 Two Typical Enclosureless Dust Collectors.

prevent the introduction of burning material into the dust collector.

The experience of many committee members leads them to believe that most dust collector explosions arise from fires within the dust collector. When the automatic bag-cleaning feature operates, it produces a dust cloud within the collector and this dust cloud is ignited by the pre-existing fire. Consequently, once a fire has become established within the dust collector, the airflow should not be shut down as that causes accumulated dust to slough off the bags, producing a dust cloud that can deflagrate. Instead, the airflow should be maintained. This limits the rate at which dust can slough off of the bags and minimizes the probability that a large dust cloud and resulting deflagration will occur. The flow of air through the dust collector also removes heat from the dust collector. Where the dust collector represents a critical or high value asset, a water deluge system can be added to minimize damage to the dust collector.

A.24.9.4.4.6.2(A) Dust collection systems 5000 cfm (2.36 m³/sec) and smaller represent less hazard due to their relatively small size and can be adequately managed with spark detection and extinguishment rather than requiring the additional expense of an abort gate.

A.24.9.4.4.6.2(B) Dust collection systems greater than 5000 cfm (2.36 m³/sec) in capacity represent a greater inherent hazard and risk and were deemed to require the inherently greater reliability of an abort gate as opposed to extinguishing systems. Where extinguishing systems can be shown to be equally reliable to the abort gate, it can be used as a performance-equivalent alternative design pursuant to Chapter 6.

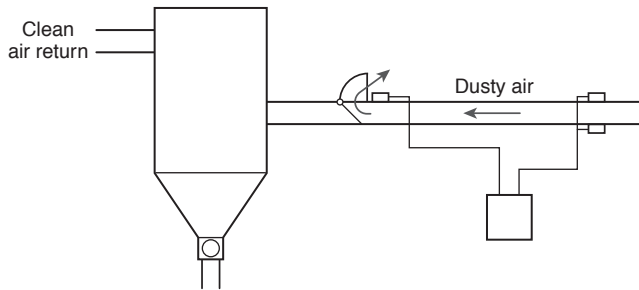


FIGURE A.24.9.4.4.6.2(a) Spark Detection and Abort Gate on Inlet Duct to the Dust Collector.

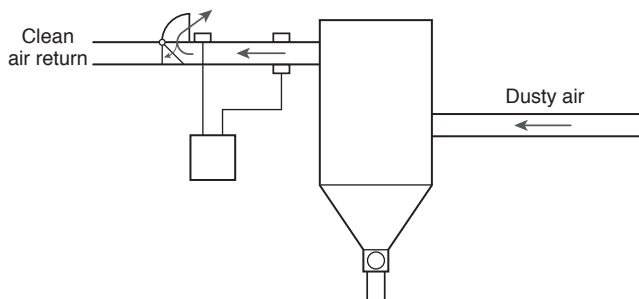


FIGURE A.24.9.4.4.6.2(b) Spark Detection and Abort Gate on Clean Air Side of the Dust Collector.

A.24.9.4.4.6.2(B)(3) Manual interaction at the abort gate is required so that the damper can be examined for any damage that could render it unsuitable for continued use.

A.24.9.4.4.7.1 Dust collectors that have rotary airlocks on their hopper outfeed sections should not be given credit for drainage through the airlocks. Dedicated drain ports with counter-weighted doors or other latching means designed to open under a slight head of water pressure are commonly provided near the bottom of hopper sections to drain fire protection water. The drain doors are adjusted so that they just barely stay closed during normal operation, and the weight of any water accumulation then causes them to open and drain off the water.

A.24.9.4.10 This equipment typically consists of high-speed rotating machinery that cuts, shears, breaks, or pulverizes wood fractions into smaller pieces. Equipment in this category includes, but is not limited to, hogs, chippers, stranders, flakers, disk refiners, hammermills, and pulverizers.

The size and power of the equipment is sufficient to create high heat and showers of sparks if any foreign material enters the equipment. Tramp metal in the material being processed is a common problem, as are rocks or other foreign material.

Fires and explosions can occur in the equipment and propagate rapidly into downstream equipment. The degree of hazard is primarily a function of the moisture content of the material being processed and the size distribution of the particulate produced by the size reduction equipment.

A.24.9.4.10.1 Steam-pressurized disk refiners are commonly used in medium-density fiberboard processes.

A.24.9.4.10.3 Dust collection pickup ducts are sometimes used to pull a slight negative pressure on equipment such that it operates at a pressure lower than ambient conditions outside the equipment. This can effectively minimize dust emissions by offsetting any slight pressurization of the equipment that occurs during the normal conveying of material.

A.24.9.4.10.4 Removal of foreign material from the process stream is the single most important method of eliminating ignition sources created by size reduction equipment. Pneumatic separators (also referred to as air separators) are preferred because they can remove not only ferrous metal, but also nonferrous metal, rocks, and other heavy foreign material that can otherwise cause sparks, frictional heat, and equipment damage. Pneumatic separators are strongly recommended when the material being processed is stored on the ground or hauled in from offsite via trucks, rail cars, and so forth. Material to be processed is commonly passed through air separators when reclaimed from storage, with magnetic separators located on the infeed conveyor to the size reduction equipment as well as other strategic points on the conveying system.

A.24.9.4.13.1 Possible protection methods could include but not be limited to the following:

- (1) Zero speed switches
- (2) Flow indicators
- (3) Level and/or plug sensors
- (4) Heat sensors
- (5) Dust level sensors
- (6) Belt tracking sensors
- (7) Power monitoring

- (8) Mechanical feeding devices equipped with a shear pin or overload detection device and alarm.
- (9) Alarms that sound at an operator control station or other constantly attended location
- (10) Direct connection of drives used in conjunction with feeders, air locks, and other material feeding devices
- (11) 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

A.24.9.4.14 Examples of bucket elevators can be Z conveyors, open bucket elevators, enclosed bucket elevators, and angled bucket elevators.

A.24.9.4.14.2 Access doors should be dusttight. Pits should be lighted and accessible and should provide ample room for cleaning, lubrication, repairs, and replacement of parts. Elevator boot sections and the spouts feeding them should be constructed so as to minimize choking of the boot.

A.24.9.4.14.4 Any motor or combination of motors utilized should be no larger than the smallest standard motor(s) capable of meeting this requirement.

A.24.9.4.14.5 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.

A.24.9.4.14.12 Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether monitoring is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation. Smaller, slower bucket elevators that generate insufficient concentrations of combustible dust might not require monitoring.

A.24.9.4.15.2 Dust collection pickup ducts are often used to pull a slight negative pressure on equipment such that it operates at a pressure lower than ambient conditions outside the equipment. This can effectively minimize dust emissions by offsetting any slight pressurization of the equipment that occurs during the normal conveying of material.

A.24.9.4.15.5 An example of a case in which no other practical location exists, and bearings or bushings can therefore be permitted inside equipment, would be hanger bearings on long screw conveyor shafts.

A.24.9.4.15.7 Gaskets or smooth machined mating surfaces are generally required for dusttight operation.

A.24.9.4.16.2 Typical methods include magnets, screens, or other methods of detection or classification and that could occur in upstream processes.

A.24.9.4.17.2 Enclosed dryers are used for drying plywood veneer and fiberboard. The most common configuration uses vertically stacked horizontal trays that convey the material through the dryer. The trays typically vary from 3 in. to 12 in. (7.6 cm to 30.5 cm) apart vertically, and the material on the top tray obstructs the lower tiers from sprinkler protection at the top of the dryer enclosure. This requires additional protection arranged at the sides for the lower tiers. These dryers typically measure 8 ft to 10 ft (2.4 m to 3 m) in cross-section and can be well over 100 ft (30.5 m) long. A series of access doors extend along both sides of the metal enclosure for maintenance and cleaning access.

A less common wicket-type configuration can be used for drying veneer. This style has the veneer held vertically between metal arms that move horizontally through the dryer, and there is little obstruction to sprinkler water discharged from the top of the dryer enclosure.

Direct-fired gas or oil burners are most common, but wood dust burners are sometimes used. Indirect heating using integral thermal oil heat exchangers is also now being used. Fans circulate heated air from side-to-side across the dryers. Several separate drying zones, defined by internal plenum walls across the dryer cross-section, are typically used for better drying control. An unheated cooling section is provided on the dryer outfeed end. These plenum walls are obstructions that need to be taken into consideration when laying out sprinkler placement.

Conventional horizontal tray-type dryers are open on both sides of the trays to allow air to flow parallel across the material surfaces. Fires in these trays can be protected by flat fan spray nozzles located along both sides of the dryer. Vertical jet-type dryers have a special design that utilizes hollow metal arms across the dryer width to supply the drying air. These arms have openings that discharge the air perpendicular to the veneer surfaces. The air supply plenum for the drying arms completely isolates the air supply side of the dryer trays from the opposite side. This means fires in these trays can be reached only by flat fan spray nozzles located along the return air side of the dryer.

Dryer enclosures commonly collect combustible dust and resin deposits on all interior surfaces, and material scraps fall and accumulate on the floor. Fires can spread rapidly throughout the entire dryer for this reason. If thermal oil is used for heating, horizontal floor or plenum sections that can collect spilled oil need to be protected from an ignitable (flammable and combustible) liquid spill fire.

A.24.9.4.17.2.1 The fire protection for the interior of the dryer should be engineered to ensure adequate water density throughout the interior of the unit. Specific engineering guidelines can be found in FM Property Loss Prevention Data Sheet 7-10, *Wood Processing and Woodworking Facilities*.

A.24.9.4.17.2.3 The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual. Cleaning by manually activating fixed water spray deluge systems is common and encouraged. This helps clear any foreign material from the deluge piping and nozzles and keeps pipe traps filled with water to help prevent dryer airflow from circulating through the open deluge piping.

A.24.9.4.17.2.4 Flash fires or building compartment deflagrations can occur across the entire area of dust deposits unless stopped by a physical barrier. Ceiling exhaust fan openings will have the largest accumulations, and the fan motors are frequent ignition sources.

A.24.9.4.17.3 Rotary dryers are used in composite panel manufacturing. Construction typically consists of steel drums that are oriented horizontally and rotate on trunnion bearings, similar to a kiln. Dryer drums are commonly 8 ft to 20 ft (2.4 m to 6 m) in diameter and 30 ft to 50 ft (9 m to 15 m) long. The drums have internal baffles, or "flights," which lift the material and advance it through the dryer as the drum rotates. Dryers are typically either single-pass or triple-pass design. In single-pass designs, the material enters one end and exits the other

end after traversing the length of the dryer once. Triple-pass designs have three concentric drums and internal baffles, which force the material to traverse the length of the dryer three times before exiting the far end.

Heated airflow is induced through the dryer to both dry the material and assist its movement through the system. Material exiting the drum can be collected in a fall-out chamber called a wind box, or conveyed pneumatically to a cyclone. Dryer exit temperature is used to control the firing rate of the burner. Direct firing of the dryer is typical, with gas, oil, or wood dust used as fuel. Occasionally, waste heat from boilers can be ducted to rotary dryers as a base-load heat source. Indirect thermal oil heating can also be used via

A.24.9.4.17.3.2 A combination of spark detection and extinguishing, water spray deluge, and process isolation devices and interlocks have proven to be highly effective and are recommended. Commonly provided protection features include the following:

- (1) Provide a spark detection and extinguishing system on the main airflow duct between the dryer drum and cyclone. The spark extinguishing system should activate every time a single spark is detected. It will reset after a few seconds (if no additional sparks have been detected), and the dryer can continue to operate. The spark counting features available in some approved spark extinguishing systems can be used to shut down dryers when an excessive number of sparks are encountered, but they should never be used as a measure of when to actuate the extinguishing spray.
- (2) Provide a second “fail-safe” detection point on the duct between the spark extinguishing nozzles and the cyclone collector. Detection at this location should be interlocked to safely shut down the dryer as follows:
 - (a) Isolate the dryer cyclone outfeed to prevent smoldering material from being conveyed into downstream process areas. This should be accomplished by stopping rotary feeders (metal tipped) or diverting material to a fire dump via reversing conveyors or diverter gates. Refer to NFPA 68 and NFPA 69 for effective isolation techniques.
 - (b) Stop material infeed to the dryer and shut off all dryer heat sources. The dryer conveying fan and dryer drum drive should be left running to purge material from the system and help prevent warping of the drum.
 - (c) Initiate an automatic water spray deluge in the dryer cyclone. Automatic sprinklers are a less desirable alternative. Provide a means for water to drain out of the cyclone. Steam should not be used as an extinguishing medium.
- (3) Provide high-temperature limit switches on the inlet and outlet of the dryer drum interlocked to initiate all of the functions in A.24.9.4.17.3.2(2), as well as actuate water spray deluge in the dryer inlet and outlet.
- (4) When the dryer duct on which spark detectors are mounted is subject to resinous accumulations, provide test lights that are mounted across the duct from each detector to facilitate remote testing. An alternative is frequent inspection and cleaning to ensure continuous operability.
- (5) Provide rotary dryers, which incorporate a “wind box” on the dryer outlet, where the majority of the conveyed material drops out, with an additional spark detection

zone, isolation measures, and water spray deluge protection similar to the main cyclone.

- (6) For dryers processing particleboard furnish or other material having a similar high concentration of fines, provide deflagration relief venting on the cyclone if it does not exhaust directly to atmosphere and on the wind box (if present). Use NFPA 68 or equivalent, for vent design. Figure W.1(c) and Figure W.1(d) show typical protection schematics and interlock logic for rotary dryers.

A.24.9.4.17.3.3 The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual.

A.24.9.4.17.4 In addition to rotary dryers, oriented strand board material can be dried in conveyor dryers (also used to dry tobacco). These dryers are similar in size to horizontal tray veneer dryers but are only about half as tall, since only one horizontal conveyor tray is used to dry and move the material through the dryer. These dryers operate at lower drying temperatures that decrease exhaust air emission problems but increase the material dwell time. As many as nine individual dryers, arranged in series, have been needed to get the required material dwell time.

Mechanical conveyors are used to feed material into and collect material from the dryers. The dryer conveyor “belt” is a continuous loop of perforated metal plates about 8 in. (203 mm) wide and 8 ft (2.4 m) long, hinged together along the long edge to form a continuous track belt. Thermal oil indirect heating is common utilizing integral oil-to-air heat exchangers.

Heated air is circulated from side-to-side through several separate heating zones, with the air distribution plenums arranged such that air flows through the perforations in the conveyor belt, perpendicular to the material surface, much like a vertical jet veneer dryer.

A.24.9.4.17.4.1 Dryer enclosures commonly collect combustible dust and resin deposits on all interior surfaces, and material scraps fall and accumulate on the floor. Fires can spread rapidly throughout the entire dryer for this reason. Also, thermal oil heating adds the potential for an ignitable (flammable and combustible) liquid spill fire inside the dryer.

A combination of spark detection/extinguishing, water spray deluge, and process isolation devices and interlocks have proven to be highly effective and are recommended as follows:

- (1) Provide protection inside individual dryer enclosures similar to that in A.24.9.4.17.2.1 for horizontal tray veneer dryers [however, (1) and (2) in 24.9.4.17.2.1(A) do not apply to conveyor dryers].
- (2) Provide approved spark detection at dryer outfeed points interlocked to reverse the take-away conveyor and dump the material in a safe location. The conveyor dryer heat source should also be interlocked to shut down, but the dryer belt should continue to run to empty the dryer.

Where fire extinguishing systems are provided for thermal oil utilization equipment, the systems should be designed to protect the equipment from a thermal oil spill fire or from the material being processed, whichever poses the more severe fire hazard.

A.24.9.4.17.4.3 The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual. Cleaning by manually activated fixed water spray deluge systems is common and encouraged. This helps clear any foreign material from the deluge piping and nozzles and keeps pipe traps filled with water to help prevent dryer airflow from circulating through the open deluge piping.

A.24.9.4.17.5 Flash dryers are used to dry wood fiber in hardboard and medium-density fiberboard manufacturing. They are basically just pneumatic transport blowpipes 5 ft (1.5 m) in diameter, with the conveying air heated to dry the material as it is conveyed. Wet wood fiber is injected via a high-pressure blowpipe into the hot induced air stream at the head end of the dryer tube. Constant diameter dryer tubes can be over 200 ft (61 m) long to get adequate material retention time in the dryer. Some configurations use vertical duct sections with increased diameters to reduce the velocity and increase the material dwell time (similar to wood pulp flash dryers). Dryer exit temperature is used to control the heat-source firing rate.

Some dryers utilize a process known as “blowline blending” where the resin binders, needed to form a rigid panel in the hot press, are added to the fiber before it is injected into the dryer. This is done for better resin mixing with the wood fiber, but it also makes the dried fiber more tacky and subject to buildup in the dryer system.

Both direct firing — using gas, oil, or wood dust burners — and indirect heating — using steam or thermal oil heat exchangers — are common.

A.24.9.4.17.5.2 Commonly provided protection features include the following:

- (1) Protect flash dryers with spark detection and extinguishing systems, isolation methods, and automatic deluge systems in cyclones similar to A.24.9.4.17.3 for rotary dryers. Flash dryer protection differs only in that there is no dryer drum. The “fail-safe” detector should also initiate a water spray deluge at the head end of the dryer tube in addition to the cyclone.
- (2) Provide high-temperature limit switches on the dryer duct at the material injection point and inlet to the cyclone. These detectors will act as backup detection to the “fail-safe” spark detector and should initiate the same functions.
- (3) Provide flash dryers with explosion protection on the dryer tube and cyclone designed in accordance with NFPA 69. If deflagration venting is the protection method selected, vents should be smooth and flush fitting on the inside to prevent material buildup.
- (4) Provide a diverter on the fiber injection pipe to direct fiber to a dump area during initial startup until the material flow is uniform.

A.24.9.4.17.5.3 The required inspection frequency is best determined for each dryer based on actual operating conditions. Weekly inspection is not unusual for dryers that utilize blowline resin blending.

A.24.9.4.17.6 Lumber that is to be dried is first prepared by stacking it in uniform loads, with each layer of lumber separated by a “sticker” of wood approximately 1 in. (25.4 mm) square. The loads of “stuck lumber” are stacked as high as 16 ft (4.9 m) on wheeled carts that run on tracks to convey the loads into each dry kiln compartment. The kiln is then closed, and

heated air is circulated through the stacks from side to side until the desired moisture content is reached. This batch process can take several hours to complete.

Kilns can be indirectly heated by steam or thermal oil heat exchangers inside the kiln enclosure, or directly heated by gas-, oil-, or wood dust-fired burners.

Once the drying cycle is complete, kiln loads are removed and placed in a “cooling shed” (usually just a canopy) to cool before the stacks are broken down for further processing of the dried lumber.

Humidifying and Tempering Ovens. The finishing of hardboard panels usually includes a tempering or humidifying process to stabilize the moisture content. This is done in large oven enclosures similar in size to lumber dry kilns. Hardboard panels are stacked up to 12 ft (3.7 m) high on wheeled carts, with spacers between individual panels to permit airflow through each stack. Indirect heating using steam heat exchangers is the most common heat source.

A.24.9.4.17.6.1 The following should also be considered when designing protection for dry kilns:

- (1) Automatic sprinklers over lumber loads should be located such that the top and sides of the lumber loads are wetted. Consideration should be given to obstructions such as heating coils and movable airflow baffles that could block sprinkler discharge when the kiln is in operation.
- (2) Flow of thermal oil through the kiln should be interlocked to stop automatically on sprinkler water flow or detection of oil loss in the kiln-heating loop. Manual shut-off is acceptable where alarms for sprinkler water flow and loss of oil annunciate at an onsite constantly attended location, the oil isolation valve is readily accessible and not exposed by a kiln fire, and the emergency response team includes a trained person assigned to this task.
- (3) Hydraulic calculations should include 500 gpm (1900 L/min) for hose streams.
- (4) A dry pipe or deluge system should be used if sprinkler piping is subject to freezing when the kiln is idle.
- (5) Sprinklers should be used with glass bulb-type thermal elements rated for approximately 50°F (28°C) above the maximum normal operating temperature.
- (6) Roofs or canopies over kiln cooling shed areas (dry lumber) and infeed areas (green lumber) should have automatic sprinkler protection designed for the equivalent height of lumber storage.

A.24.9.4.17.6.6 The required inspection frequency is best determined for each dryer, based on actual operating conditions. Weekly inspection is not unusual.

A.24.9.4.19.1.1 A number of options are available for the protection of continuous presses, including, but not limited to, water spray systems, water mist systems, and gaseous extinguishing systems. The design of the protective features should address the unique characteristics of the press.

The system should provide sufficient volume to extinguish any fire in or on the press without causing any structural damage to the belts, hydraulics, oil hoses, or press frame. In case of an oil leak, the system should be able to control the fire until emergency responders arrive.

Continuous presses were introduced in North America in the late 1980s. Continuous presses can be found as large as 33 ft to 160 ft (10 m to 55 m) long, 6 ft to 10 ft (1.83 m to 3.05 m) wide. The fiber mat enters at the inlet and the finished board exits at the outlet at speeds of up to 295 ft/min (1.5 m/sec). This high-production equipment presents a number of new protection design challenges, as follows:

- (1) 20,000 gal to 30,000 gal (75,700 L to 113,550 L) of thermal heat transfer oil operating well above its flashpoint
- (2) Thousands of gallons of hydraulic oil
- (3) Lubrication grease covering frames and surfaces
- (4) Dust, fiber, glue, and release agent, all of which are combustibles and make up the mat
- (5) Friction of moving parts
- (6) Flexible low-pressure hoses for hot thermal oil
- (7) Flexible high-pressure hoses for hydraulic oil
- (8) Raw material of dry wood fiber, resins, glues, and release agents, all of which are combustibles, moving forward under high pressure and temperatures well in excess of 300°F (149°C)
- (9) Return belts that travel in upper and lower heat tunnels that are subject to buildup of fiber, oil, grease, and fumes
- (10) The board's ignition upon exposure to oxygen when exiting from the press
- (11) Operator errors

Protection by conventional sprinkler systems and deluge systems can be very detrimental to the integrity of the press. Such systems are slow and use large volumes of water, causing too-rapid cooling, which can cause damage to steel frames, hot platens, and steel belts. It is advisable to employ optical flame and spark detection systems for early detection. The detectors activate the fine water mist spray nozzles that protect the area of the fire. A press can typically be split up in five independent zones: inlet, middle, outlet, upper, and lower heat tunnels. The fine droplets will hit the fire and immediately turn into steam, expanding more than one thousand times. The conversion of water to steam cools, and the expansion smothers the fire.

The small droplet size greatly reduces the possibility of damage to steel frames and instrumentation or of warping of the belt. Fine water spray typically requires one-third of the water volume of conventional systems and less cleanup time, less damage, and shorter downtime. Fine water mist sprays have proven themselves most successful in Europe and elsewhere.

The Technical Committee knows of dozens of incidents where continuous presses have caught fire. Most of the fires have caused less than one million dollars in damage, with a few running into multimillion dollars. Conventional firefighting using hoses has caused more damage, due to the water, to the press frames, belts, and instrumentation than was caused by the initial fire.

Most fires have occurred at the outlet and the upper heat tunnel. The majority of fires can be referred to human error in operation or programming. Most of the fires have occurred in Europe, where the majority of presses are in operation.

A.24.9.4.19.2.2 Where thermal oil heating is employed, there is a greater risk of ignition and greater availability of fuel. This condition can warrant the use of deluge protection rather than closed head sprinkler protection.

A.24.9.4.23 Dryer systems can require pollution control equipment to reduce emissions of both particulate (e.g., dust, ash)

and vapors (e.g., volatile organic compounds, or VOCs, known in the industry as “blue haze”).

Commonly used particulate collection equipment includes bag filters, wet and dry scrubbers, electrostatic precipitators, and other specially designed hybrid collection devices such as electrified filter beds (EFBs).

Commonly used vapor collection or incineration equipment includes regenerative thermal and catalytic oxidizers (RTOs and RCOs), incineration chambers, and bio-filters. In all cases, the ducts between dryers and vapor collection or control equipment are subject to buildup of combustible deposits. Although insulating ducts can help reduce the rate of condensation deposits, they cannot be relied upon to totally prevent them. In some instances, dryer air exhaust can be ducted into the combustion air supply for fuel burners.

A.24.9.6.3.1 Bearings in dusty or inaccessible areas where overheating can cause ignition of fires or explosions should be equipped with journal temperature alarms.

A.24.9.6.6 Grounding and bonding information can be found in NFPA 77. Because cellulosic materials are highly hydroscopic, active humidity controls can be useful in limiting the tendency to accumulate static electrical charge.

A.24.9.6.7.2 Wherever possible, heating units should be installed in compartments separate from woodworking and wood processing activities and processes. Guidance is available in FM Property Loss Prevention Data Sheet 6-7, *Fluidized Bed Boilers*, and FM Property Loss Prevention Data Sheet 6-13, *Waste Fuel-Fired Facilities*.

A.24.9.6.11 Collection points used for manual cleanup, such as vacuum hoses or floor sweeps, should incorporate features for prevention of foreign material entry. Magnetic separators, grates, or screening are typical protective features.

A.24.9.6.11.4 Consideration should be given to the potential for overheating due to dust entry into bearings. Bearings should be located outside the wood waste stream, where they are less exposed to dust and more easily inspected and serviced. Sealed bearings are preferable.

A.24.9.6.14.2 Refer to NFPA 499.

A.24.9.6.15.2 Building exhaust fans over hot presses, veneer dryers, and finishing area or booth exhaust fans are particularly susceptible to this problem.

A.24.9.6.16 Serious consideration should be given to installing lighting that is suitable for Class II, Division 2, Group G hazardous locations in all woodworking and wood processing areas where wood dust is likely to occur. Such lighting will permit the use of blowdown methods for cleaning while the lighting is operating. Failure to use lighting suitable for Class II, Division 2, Group G hazardous locations will necessitate locking out and tagging out the lighting power supply before commencing blowdown, and explosion-proof lighting will have to be provided on a temporary basis while blowdown is being conducted.

A.24.9.6.18 Most fires involving woodworking and wood processing facilities are ignited by the process equipment. Whenever wood or wood-derived products and materials are cut, shaped, planed, or smoothed, heat is generated in the process. This heat can be sufficient to raise the wood or wood-derived materials to their ignition point, igniting a fire. It is important to note that most cellulosic materials will begin to

pyrolyze (decompose due to heat) as their temperatures are raised above 392°F (200°C). At these temperatures, this process is endothermic, requiring the investment of heat to continue. However, once the temperature of the wood or wood-derived material attains temperatures in excess of approximately 536°F (280°C), the chemical reactions involved in pyrolysis change and become exothermic, producing more heat than is needed to continue the process. This results in the ignition of the wood waste generated by the equipment. Whenever the wood is visibly discolored (i.e., singeing or charring), an ignition has occurred and burning material has been introduced into the dust collection (wood waste conveyance) system.

A.24.9.6.18.1 High feed rates generate more heat per unit of time and unit of wood processed. This increased rate of heat generation increases the likelihood that embers and sparks will be produced that can lead to the ignition of wood particulates conveyed in the pneumatic wood waste removal system. This is particularly important when working with wood species that exhibit wide variations in density and hardness with the same board, such as maple, oak, cedar, and hickory.

A.24.9.6.18.2.1 The quantity of heat generated during a wood-working operation is affected by the sharpness of the tool(s). Whether the tool is a saw, shaper, router, planer, or one using abrasives, properly sharpened cutters operate more coolly and are far less likely to ignite stock or wood waste.

A.24.9.6.18.2.2 Abrasive belts have been identified as the source of ignition in a number of serious fires. This necessitates careful management of the abrasive condition. Once grit begins loading up, all of the power dissipated by the machine motor is essentially converted to frictional heat. Extreme care should be employed with abrasive shaping and surfacing machines for this reason.

A.24.9.6.19.2 In some cases, the use of spark-resistant tools might be advisable.

A.24.9.6.20.1 There have been some reports of autoignition of wood particulates where large quantities of particulates have been stored undisturbed for extended periods of time. The common denominator in these events has been particulates with relatively high polymerizable oil contents stored in large piles for extended periods of time where the heat generated by the polymerization reaction cannot easily and rapidly dissipate.

A.24.9.6.20.3 Linseed, tung, and similar oils have been identified as having a spontaneous ignition history.

A.24.9.8.2.2 Some dust collectors, especially bag filters designed to collect dust on the inside of the filter media, can operate without any enclosure, but they sometimes have very lightweight, self-venting enclosures just for weather protection.

A.24.9.8.2.2(1) When dust collectors are designed and installed in accordance with 24.9.8.2.2(1), administrative controls such as lockout/tagout or inspection programs to assure that access hatches are in place before equipment is operated are recommended.

A.24.9.8.2.2(2) The manufacturer of the listed deflagration suppression system should be consulted to determine the maximum reduced deflagration pressure to be expected with their protection hardware.

A.24.9.8.2.2(3) If relief pipes are used in conjunction with deflagration relief vents to direct the vented gases to a safe location, the reduced deflagration pressure will be higher than

if no relief pipes were present. Deflagration relief vent design and reduced deflagration pressure requirements are found in NFPA 68. If listed flame-quenching devices are used in conjunction with deflagration relief vents to extinguish flames in the vented gases, the reduced deflagration pressure will be higher than if no flame-quenching devices were present. The manufacturer of the listed flame-quenching device should be consulted to determine the maximum reduced deflagration pressure to be expected with the protection hardware.

A.24.9.8.2.3 Although criteria are given for designing and operating pneumatic conveying ducts close to or above the MEC, it is safer and preferable to operate below this threshold by keeping airflow sufficiently high to prevent the maximum concentration of dust in the duct from exceeding 25 percent of the MEC. The one exception to this is bulk transport using high-pressure ductwork that utilizes smaller-diameter and stronger duct than low-pressure systems. These systems transport particulate in very high concentrations and have an excellent loss history relative to deflagration propagation or damage.

A.24.9.8.2.3(1) High-pressure conveyance lines (blowpipes) made of steel or iron pipe with Schedule 40 or greater wall thickness normally meet the strength requirement of 24.9.8.2.3(1). Administrative controls such as lockout/tagout or inspection programs to ensure that access hatches are in place before equipment is operated are recommended.

A.24.9.8.2.3(2) The manufacturer of the listed explosion suppression system should be consulted to determine the maximum reduced deflagration pressure to be expected with their protection hardware. Welded steel of 12-gauge minimum thickness is normally strong enough to prevent failure during an explosion, especially for small ducts.

A.24.9.8.2.3(6) Ducts located outdoors do not pose an undue potential for property damage or expose plant personnel or the public at large to the risk of injury from rupture of the duct. Therefore, they might not need strong construction.

A.24.9.8.2.4 Refer to NFPA 68.

A.24.9.8.2.5 This subsection includes additional requirements for size reduction equipment deemed to have a deflagration hazard.

A.24.9.8.2.5.2 The manufacturer of the listed explosion suppression system should be consulted to determine the maximum reduced explosion pressure to be expected with their protection hardware.

If relief pipes are used in conjunction with deflagration relief vents to direct the vented gases to a safe location, the reduced explosion pressure will be higher than if no relief pipes were present. Deflagration relief vent design and reduced explosion pressure guidelines are found in NFPA 68. If listed flame-quenching devices are used in conjunction with deflagration relief vents to extinguish flames in the vented gases, the reduced explosion pressure will be higher than if no flame-quenching devices were present. The manufacturer of the listed flame-quenching device should be consulted to determine the maximum reduced explosion pressure to be expected with their protection hardware.

Size reduction equipment located outdoors that does not pose an undue property damage loss potential to the property owner or expose plant personnel or the public at large to the

risk of injury from an explosion might not need strong construction or any special protection.

A.24.9.8.2.6.2 Administrative controls such as lockout/tagout or inspection programs are recommended to ensure that access hatches are in place before equipment is operated.

A.24.9.8.3.1 The intent of this section is to prevent spread of fires and explosions via conveying systems from high-risk processes into work spaces, storage facilities, or other critical processing systems beyond those immediately involved. It is not the intent to isolate each and every piece of conveying equipment from each other. Consideration of when and where to isolate should be based on the frequency of ignition sources and the potential severity of a loss (e.g., property damage, downtime, and personal injury).

A.24.9.8.3.1.3 Except for passive devices, such as flame front diverters, backblast dampers, and material chokes, detection and speed of actuation of the device is critical. For fire isolation, the normal material conveying speed is used to determine the necessary speed of isolation devices. For deflagrations,

however, flame propagation through conveying systems will be much faster than normal conveying speeds, and it can also accelerate. Isolation design, device construction, and installation should be done only by engineering consultants, manufacturers, and vendors familiar with the hazards and capabilities and limitations of the hardware. Table A.24.9.8.3.1.3 lists some commonly used isolation devices.

A.24.9.9.3 In areas containing thermal oil equipment or piping, a 20 lb to 30 lb (9 kg to 14 kg) dry chemical-type extinguisher is preferable. Portable or fixed foam or aqueous film forming foam (AFFF) extinguishing equipment is an acceptable alternative.

A.24.9.9.4 Inside, 1½ in. (38 mm) hose stations are recommended throughout all major woodworking facilities. Directional water spray nozzles or combination straight stream water spray nozzles are recommended, since careless use of straight hose streams can cause dust explosions by throwing hazardous quantities of dust into suspension. NFPA 600 should be utilized as a guide for employee training.

Table A.24.9.8.3.1.3 Commonly Used Isolation Devices

Isolation Device	Application	Limitations
Diversion Devices		
Abort gate	Fire and deflagration	Used on pneumatic conveying ducts. Most practical on positive pressure pneumatic systems (two abort gates needed for negative pressure systems).
Pant leg gate	Fire and deflagration	Used on gravity flow chutes at material transfer points.
Slide gate	Fire only	Used on the bottom of mechanical conveyors that slide material through the conveyor enclosure (e.g., screw and flight conveyors).
Reversing conveyor	Fire only	Used with mechanical conveyors (usually screw conveyors). Not effective with dusty material unless other blocking devices (e.g., rotary feeders) are also used.
Flame front diverter	Deflagration only	Used on pneumatic conveying ducts.
Blocking Devices		
Rotary feeders	Fire and deflagration	Must have metal-tipped vanes with narrow wall gap 0.18 mm (0.007 in.). Rubber-tipped vanes cannot be relied on. Must be stopped to remain effective.
Slide gate	Fire and deflagration	Used to block pneumatic ducts, chutes, and so forth. Usually actuated with high-pressure gas cylinder.
Flame front extinguishers	Deflagration only	Single-shot pressurized chemical extinguishers, typically used on ducts or enclosed conveyors.
Backblast dampers	Deflagration only	Used on pneumatic systems to prevent flow counter to normal flow.
Material chokes	Deflagration only	Normally used on mechanical screw conveyors or at material transfer points.

Annex T also discusses various types of explosion isolation devices.

A.24.9.9.5 Automatic sprinkler protection is recommended throughout all major woodworking facilities. Press pits, press hoods, and hood ventilating fans should be protected by automatic sprinkler systems, deluge systems, or both. It is important that sprinkler and deluge heads be located so that hard-to-reach places, such as spaces between press cylinders, are properly protected. The design criteria established in this standard reflect research, testing, and loss history accumulated by the industry and internationally recognized research laboratories.

A.24.9.9.6 The minimum testing and maintenance frequency for spark detection and extinguishing systems should be as given in Table A.24.9.9.6.

An approved spark detection and extinguishing system should be considered to quench burning material before it can be conveyed into the collecting equipment.

Also, when bag filters are used, with the conveying airflow fan located ahead of the bag filters, a high-speed abort gate activated by infrared spark detectors should be used to divert burning material before it can enter the bag filter. (Refer to T. Frank, "Fire and Explosion Control in Bag Filter Dust Collection Systems.")

A.24.9.9.8.2 Adequate drainage (automatic dumping) should be provided to prevent structural collapse.

A.24.9.9.8.3 Equipment having a history of producing frequent sparks includes, but is not limited to, large belt sanders and planers having automatic feed systems, hammermills, pulverizers, and flakers. This protection is generally employed to protect the downstream equipment rather than the duct itself.

This protection also deserves consideration on dust collection systems for less hazardous equipment (e.g., saws) if the loss potential for property damage or interruption to production is high.

A.24.9.9.8.3(2) Abort gates can be used on systems that have the air-moving device located upstream of any dust collection equipment (i.e., positive pressure systems). This arrangement facilitates clearing the ductwork of all burning material by stopping material infeed and leaving the fan running when the abort gate activates. This is the recommended arrangement and operating sequence when this alternative is used. Figure A.24.9.9.8.3(2) (a) shows the normal and aborted airflow conditions.

In situations where the fan is on the clean side and external to the AMS, there is a simple way to arrange an abort gate to divert burning material from the dust collector, which achieves the need to purge the upstream ducts of material. It is imperative that the fan (AMD) remain running and that the fuel source be eliminated to clear the duct. This is shown in Figure A.24.9.9.8.3(2) (b).

A.24.9.9.8.4 Adequate drainage should be provided to prevent structural collapse. In addition, a means should be available to remove the contents other than through the facility process to permit the removal of burning material without threatening the rest of the facility. Storage bins and silos should be located outside the building on independent supporting structures and should be accessible for firefighting. It is not advisable to locate bins or silos on the roofs of buildings.

A.24.9.9.8.5 This subsection includes additional requirements for size reduction equipment deemed to have a fire hazard.

A.24.9.9.8.6 Typical examples of these conveyors are most rubber belt conveyors and bucket elevators. Misalignment is commonly detected by switches mounted near the belt edges. A mistracking belt will contact the switch and shut down the drive. Rotary motion detectors on belt drive and tail spools are commonly used to detect a slipping belt. Motion detection on the drive spool with no corresponding motion detected on the tail spool would indicate a slipping belt and shut down the drive.

Table A.24.9.9.6 Minimum Testing and Maintenance Frequency for Spark Detection and Extinguishing Systems

Item	Operation	Weekly	Monthly	Semi-Annual	Comments
Control panel	Clean	X			Visual inspection of all warning/operational lights.
Emergency power	Test			X	See manufacturer's battery test procedure.
Detector and spray nozzle	Test	X*			See manufacturer's detector and spray nozzle test procedure. Remove and inspect strainers.
Detectors/test lights	Maintenance	X†			Inspect and clean.
Water lines	Flush		X		Flush for 2 minutes. Remove and inspect strainer.
Booster pump (if provided)	Test		X		See manufacturer's booster pump test procedure.
Freeze protection	Inspect		X		Check at plant winterization and monthly during freezing.
Rapid speed abort gates	Test			X	See manufacturer's test procedure.

*See manufacturer's test procedure. Where daily automatic detector response testing is provided by external means (test lights), monthly inspection is acceptable.

†The frequency of cleaning should be adjusted, based on the experience at each detector point. Detectors found to be dirty during scheduled cleaning should have their cleaning frequency increased, and those found to be clean can have their cleaning frequency decreased.

Rubber belt conveyors represent a special design challenge that is not specifically addressed in NFPA 13. Valuable additional guidance is available in FM Property Loss Prevention Data Sheet 7-11, *Conveyors*.

A.24.11.1 Refer to FM Property Loss Prevention Data Sheet 7-99, *Heat Transfer Fluid Systems*, or NFPA 87.

As shown in Figure A.24.11.1, a typical thermal oil heating system includes the following:

- (1) Thermal oil heater

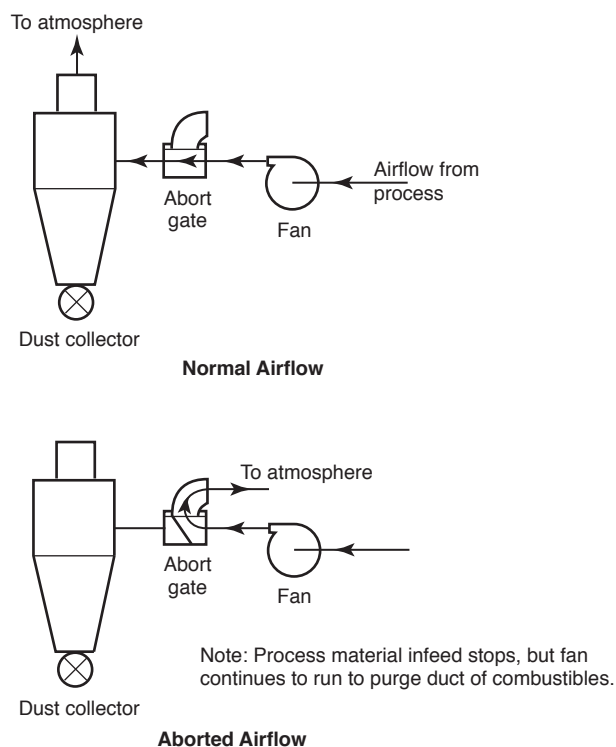


FIGURE A.24.9.8.3(2)(a) Aborting of Positive Pressure Systems.

Diversion of sparks with a single abort gate upstream of dust collector

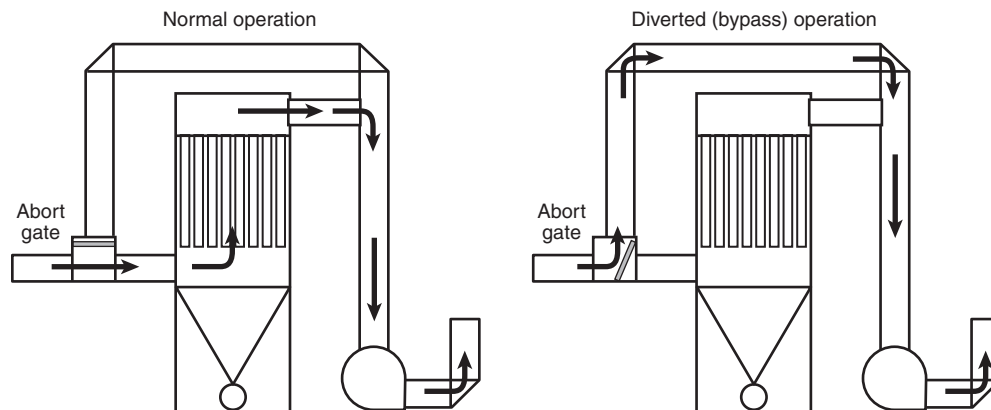


FIGURE A.24.9.8.3(2)(b) Diversion of Sparks with a Single Abort Gate Up-Stream of Dust Collector.

- (2) Primary circulation loop and pumps to keep oil flowing through the heater
- (3) Secondary thermal oil loop(s) to circulate oil through the utilization equipment
- (4) Expansion tank to hold the increased volume of the oil as it is heated
- (5) Drain tank to receive oil intentionally drained from the system or expelled through system relief valves, overflow pipes, or vents

Firing can be by conventional gas or oil burners or by wood dust suspension burners. Large heaters can burn wood waste on a grate, in a fluidized sand bed, or by more complex gasification methods that partially burn and gasify wood waste on a grate using sub-stoichiometric under-fire airflow, and complete the combustion in an upper plenum using secondary air injection. Combustion gases, typically in the 1700°F to 2000°F (927°C to 1093°C) range, then heat the thermal oil via radiant and/or convection air-to-oil heat exchangers. The heat exchanger can be a separate, stand-alone unit or an integral part of the heater. Refractory lining is needed for the burner, heat exchanger, and any interconnecting duct until gas temperatures are reduced to about 800°F (427°C) or less. Conventional water-tube boilers have been adapted to heat thermal oil, with thermal oil replacing the water.

Nonvaporizing thermal oil systems are the norm in wood processing or woodworking occupancies and are preferred because they do not pose a significant room explosion hazard. Vaporizing systems are rare and are discouraged because an oil leak can expel boiling oil/vapor into the surrounding space and form an explosive atmosphere.

Most nonvaporizing systems in these occupancies have expansion tanks operating at atmospheric pressure, with open vents to equalize pressure in the expansion tank as the oil level changes during operation.

Some nonvaporizing systems have oversized expansion tanks that are completely sealed and operate under slight pressure [less than 15 psi (103.426 kPa)] as the heated oil rises in the tank. This arrangement eliminates the possibility of overflowing the expansion tank.

The thermal fluids used are special organic or synthetic oils developed for this type of application, with flash points of several hundred degrees Fahrenheit. For maximum thermal efficiency, the oil is usually heated above its flash point, making an oil spill especially hazardous. Also, because of the high oil temperature, it is sometimes necessary to keep the oil circulating through the heat exchanger at all times to prevent oil breakdown and tube fouling, especially with wood waste-fired heaters. Diesel-driven pumps or emergency generators are usually provided for this purpose in case of a power outage, with an emergency bypass cooling loop to extract heat from the oil when normal utilization equipment would also be inoperable. This continuous oil pumping can increase damage if an oil leak and fire involving the primary heating loop occurs, and special controls and interlocks are needed.

Thermal oil heating systems are used to heat equipment such as lumber dry kilns, plywood veneer dryers, plywood and composite board presses, and wood particulate and fiber dryers, and even for building heat.

A.24.11.1.1(1) The larger systems in use in wood processing plants have total oil capacities up to 45,000 gal (170,345 L). The smaller ones hold as little as 100 gal to 200 gal (379 L to 757 L).

A.24.11.1.1(2) Thermal oil flow rates can be as high as 13,000 gpm (49,210 L/min) in large multiopening press secondary loops. Primary loops on these systems typically flow oil up to 2500 gpm (9464 L/min). The very small systems containing just a few hundred gallons could have flow rates under 100 gpm (379 L/min).

A.24.11.1.1(3) The ability to detect loss of fluid in the system is critical in reducing the amount of oil that can spill. Small leaks can also spill large quantities of oil over time if not detected. Various leak detection methods along with their benefits and limitations are listed in Table A.24.11.1.1(3).

A.24.11.1.1(4) If the method of leak detection used does not specifically identify the section of the system where the leak is occurring, controls and interlocks will need to isolate as many sections of the system as required to keep the largest credible

spill at an acceptable level, regardless of the location of the leak.

The most common isolation technique is to close off all secondary thermal oil loops to reduce the exposure to important equipment. Where feasible, the primary loop should not leave the cutoff heater area. This will keep the secondary loop connections and control valves in the dedicated cutoff area. If the secondary loop piping is long and/or of large diameter, it can be necessary to have additional valves on pipe runs to reduce the amount of oil that can spill.

Another isolation technique is to close off the downcomer pipe from the expansion tank, removing that volume from the spill potential in the primary and secondary loops. Concurrently, a drain line on the expansion tank is sometimes opened to empty the expansion tank into a storage tank or other safe location.

Isolation of the heater oil piping is a special problem for heaters that need to keep oil flowing due to very high oil temperatures, fuel supplies that cannot be instantly shut off (e.g., wood pile burners), and/or high latent heat storage in heater refractory. Stopping oil flow in these instances before temperatures are reduced can foul the heat exchanger tubes, necessitating their cleaning or replacement. Emergency diesel-driven pumps and emergency bypass cooling heat exchangers are usually provided in these cases so that secondary loops can be isolated without shutting down the primary loop. One major exception to stopping the flow through these heaters is when an oil leak and fire are occurring in the heat exchanger itself. In this case, the desirable action is to actuate an extinguishing system in the heat exchanger, shut down the primary circulation pump(s), and drain or isolate the oil in the expansion tank. In addition to oil leak detection, a second detection means, such as high stack temperature or high stack combustibles, is usually provided to confirm a fire in the heat exchanger.

Valves that need to operate during a spill emergency should be fail-safe, and if manually actuated, should have remote actuation capability. One common method of implementing this is to use spring-loaded ball valves with pneumatic actuators. The spring would cause the valve to go to the full open or full closed position, whichever is the appropriate safe position, when control air pressure is removed. The valve can be made fail-safe by installing a section of plastic tubing in the control air supply line at the valve. A leak and/or fire at the valve will burn through the plastic tubing and cause the valve to go to the safe position.

For all sections of piping that are deadheaded by closed isolation valves, it is necessary to provide a means of negative pressure relief as hot oil cools to prevent possible collapse of piping, vessels, and so forth. This is most easily done by drilling a small hole through isolation valve gates/balls and through check valve clappers, or by small open tubing around the isolation valves to permit a very small amount of oil to flow as it cools and contracts. If the expansion tank has not been isolated, it will supply oil slowly to provide the necessary negative pressure relief to the system. If it has been isolated, its isolation valve should also have the small drilled hole or bypass tubing to allow the expansion tank to equalize the negative pressure.

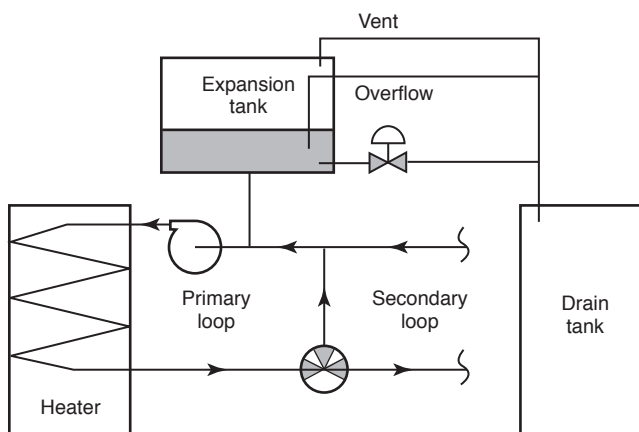


FIGURE A.24.11.1 Typical Thermal Oil Heating System Components.

Table A.24.11.1.1(3) Leak Detection Methods: Benefits and Limitations

Leak Detection Method	Benefits and Limitations
Expansion tank low oil limit switch Installed near bottom of tank.	Simple, but tank is emptied before alarm initiated. Can't differentiate between large and small leaks. Might be enough for very small systems.
Expansion tank low oil deviation switch Installed higher in tank, below the normal maximum oil level when system is at operating temperature.	Simple, and alarms quicker than low limit switch, but changes in oil type, quantity, or operating temperature will change alarm point. Must be bypassed during startup heating process.
Expansion tank flowmeter Installed on downcomer pipe connecting tank with primary oil loop combined with control programming to continuously monitor flow rate.	More complex control logic, but can detect early loss of oil if flow rate is greater than instrument sensitivity. Might not detect small leaks over time.
Expansion tank dynamic oil level detection Using hydrostatic pressure transducer combined with control programming to continuously monitor oil level.	Most complex control logic, but most flexible and most accurate. Can detect absolute oil level changes as small as ± 6.35 mm (0.25 in.), up or down, as well as rate of change. Self-adjusts to oil level in tank during startup.
Dual flowmeters On specific pipe sections (e.g., inlet/outlet of loops, heaters, etc.) combined with control programming to continuously monitor differential oil flow.	More complex control logic, but can identify larger leaks in specific pipe sections. Mass flowmeters required for accuracy if change in oil temperature (i.e., volume) between meter locations. Will not detect small leaks below combined accuracy of two flowmeters.
Single flowmeters On pipe sections combined with control programming to continuously monitor oil flow.	Control logic is simpler, but cannot detect smaller leaks below the accuracy of the flowmeter.
Low oil pressure switches or pressure transducers Combined with control programming to continuously monitor oil pressure.	Control logic is simpler, but cannot detect smaller leaks below the accuracy of the instrumentation. Cannot differentiate between other conditions causing low pressure (e.g., pump failure, partially closed valve, etc.). Not appropriate where low oil pressure starts emergency oil pumps.
Liquid spill detection Near floor level in pits, drains, or sumps around specific equipment.	Simple and able to locate leaks at specific equipment. Might be able to detect leaks early if containment area is small. Subject to false alarm from other liquids such as wash-down hoses, etc.
Acoustic transducers On specific pipe sections combined with sophisticated monitoring control system to continuously listen for abnormal sound signatures.	Potentially able to detect small leaks, but requires calibration setup to filter out normal system sounds. No experience available on feasibility of this method on thermal oil systems.

A.24.11.1.1(5) When pumps are shut down, gravity will provide the motive force for oil to flow to system low points. Backflow can occur counter to the normal flow direction under these circumstances, so all flow paths, valve types and locations, and relative elevations should be considered when designing isolation systems. A secondary loop arrangement is shown in Figure A.24.11.1.1(5)(a) with a three-way control valve on the secondary loop oil supply leg.

During normal operation, the three-way valve diverts a portion of the primary loop flow into the secondary loop to maintain temperature in the utilization equipment. Oil can freely flow into or out of the expansion tank as the oil volume changes with temperature. If an emergency shutdown occurs due to an oil leak in the secondary loop, the pump is stopped and the three-way valve moves to full bypass position, isolating the normal oil infeed line to the secondary loop. However, because the normal secondary loop return line does not have a check valve, the expansion tank and any oil pipe higher than the point of breakage in the secondary loop can drain back through the return pipe. A check valve is needed as shown to reduce the largest credible spill from a break in the secondary loop. Other means would be needed (e.g., rapid drain of the expansion tank and isolation valve on expansion tank down-comer pipe) to isolate the expansion tank if the leak were in the primary loop.

In Figure A.24.11.1.1(5)(b) a three-way oil control valve is located on the secondary loop return leg.

In this case, gravity flow will feed oil into the secondary loop in the normal flow direction, so a check valve cannot be used to stop the unwanted flow. An automatic isolation valve interlocked with the emergency shutdown sequence is needed to block the flow. This valve should fail in the closed (safe) position. Because this arrangement is more complex and requires active interlocks and valves, it is less reliable than the operation in Figure A.24.11.1.1(5)(a). Placing the three-way control valve on the oil supply leg with a simple passive check valve on the return leg is, therefore, the preferable arrangement.

Figure A.24.11.1.1(5)(a) and Figure A.24.11.1.1(5)(b) are just two examples of flow control valving arrangements used on the larger thermal oil systems. Smaller systems might not have a secondary loop or might have just a single modulating ball valve for flow control. However, the need to evaluate all paths that oil can take to reach a point of leakage is no different for smaller systems. The same isolation concepts apply when trying to control or minimize the amount of oil that can leak, regardless of the system size.

A.24.11.1.2 It can be anticipated that 1 gal (3.79 L) of spilled oil will spread out and cover approximately 20 ft² (1.9 m²) on a flat floor.

A.24.11.1.3(3) It can be assumed that a pool of thermal oil will burn down at a rate of about 1 in. (25 mm) every 7 minutes.

A.24.11.2 When thermal oil is used for building heat, a central heat exchanger should be provided to heat a nonflammable liquid, such as a water/glycol solution, that can then be piped throughout the facility without increasing the fire hazard. This method is strongly preferred even though exceptions are given to allow direct pumping of thermal oil.

While welded connections minimize the risk of an oil leak, there have been significant losses involving thermal oil leaks from cracked welds. If the areas having thermal oil heating

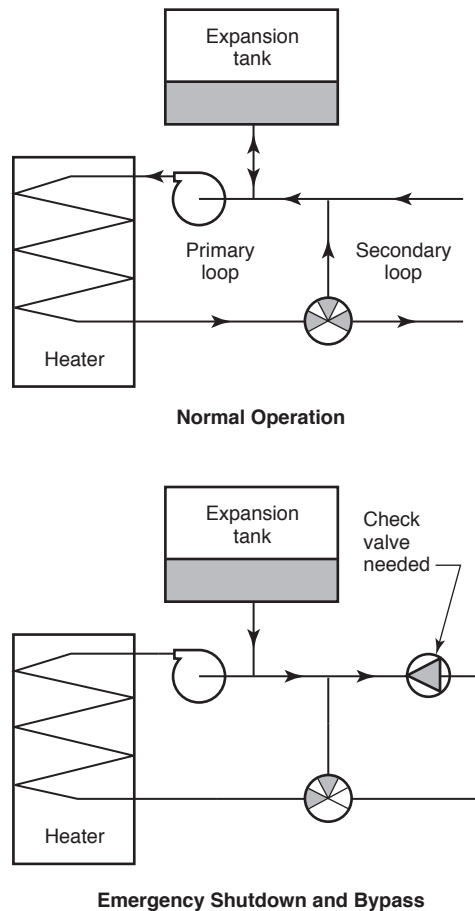


FIGURE A.24.11.1.1(5)(a) Three-Way Valve on Supply Leg.

have automatic sprinkler protection, it is good practice to design the sprinklers for the thermal oil hazard if that poses a higher fire demand.

The largest credible thermal oil spill should take into consideration the ability of the thermal oil system to automatically detect oil leaks, shut down pumps, and isolate piping loops. The sprinkler demand for a thermal oil spill fire is normally greater than the demand for the woodworking occupancy. Thus, greater cost is incurred for the sprinkler protection of the facility when this exception is followed. This additional cost will normally pay for the nonhazardous fluid heat exchanger system.

When alternatives to 24.11.2(1) and 24.11.2(2) are elected, they demand far greater sprinkler delivery density and the design area can be larger, impacting sprinkler system design.

A.24.11.3.3 Mist explosions have been known to occur when thermal oil above its boiling point has been released into an enclosed area. The preferred location for a vaporizing system is, therefore, outside or in a detached building.

A.24.11.3.6 For example, when the supports for the thermal oil equipment have fireproofing or automatic sprinkler protection of adequate design to keep structures from collapsing for the expected duration of the largest credible thermal oil spill fire, the hazard is not increased if ground sloping is not employed. In this case, the ground slope requirement can be

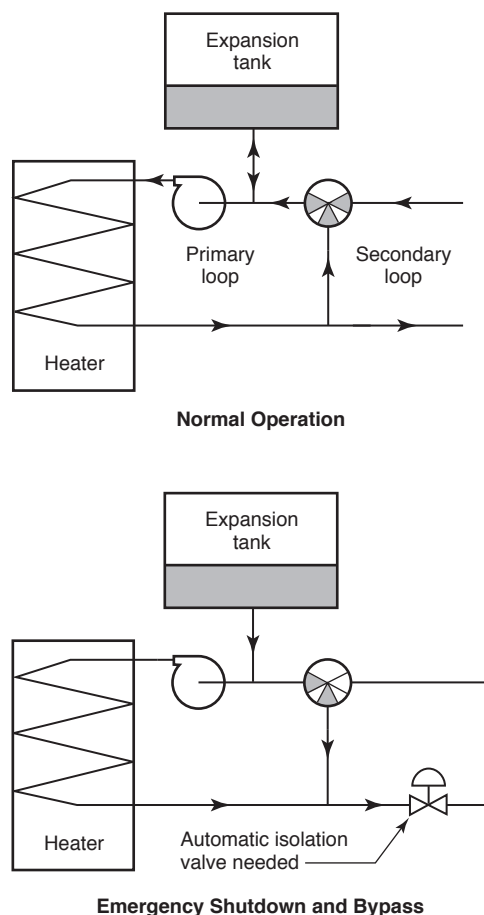


FIGURE A.24.11.1(5)(b) Three-Way Valve on Return Leg.

waived on the basis of the performance-equivalent alternative design.

A.24.11.3.7 An example of such a control room is the main forming line and press control room typically found in composite panel plants. Windows in the control room walls will also need to be listed with the same fire rating as the wall or be otherwise protected by automatic fire shutters or dedicated window sprinklers.

A.24.11.4.2 This requirement is commonly accomplished by piping the discharge outside or into a thermal oil storage tank.

A.24.11.5.1 Overhead routing of thermal oil piping in buildings should be minimized where practical. Options to overhead pipe runs in buildings include running piping underground, outside, or in floor trenches. Proper clearance from combustibles should be determined based on the maximum operating surface temperature of the pipe, taking into account any pipe insulation.

A.24.11.5.2 See 24.11.1.1 for guidelines on determining the size of the largest credible thermal oil spill, as referred to in item (1) of the Exception, and commonly used methods for reducing it.

A.24.11.5.4 For larger systems with higher pumping rates, isolation normally requires a thermal oil leak detection system, automatic-closing isolation or three-way valves on loop supply

legs, check valves to prevent backflow through return legs, and so forth. Refer to 24.11.1.1 for guidelines on determining the size of the largest credible thermal oil spill and commonly used methods for reducing it.

A.24.11.5.7 Closed-cell, nonabsorbent insulation is preferred unless all piping and joints are welded. Fibrous or open-cell insulation can act as a wick and soak up leaking oil. The oil can then break down in the insulation and eventually autoignite. Dust accumulations should be routinely removed from all piping on a regular basis.

A.24.11.6.1 These criteria should apply, even if the tank is operated as an atmospheric tank, as a safeguard against rupture from overpressurization due to overfilling the thermal oil system, inadvertent accumulation of water from condensation or processes, and so forth.

A.24.11.6.2 This requirement is commonly accomplished by piping the vents and drains into a thermal oil storage tank or to a safe area outside.

A.24.11.6.3 This requirement is best accomplished by draining the oil into a low-level storage tank. The drain line should be sized such that the majority of the oil will go to the drain tank rather than out a leak elsewhere in the system to accomplish the intent of limiting the size of a spill. Adequate breather vents should be provided, based on the maximum emptying or filling rates.

In some cases, it can be necessary to also have a remotely operable blocking valve or a three-way valve on the pipe connecting the expansion tank to the primary loop piping to quickly and completely isolate the expansion tank during an emergency drain. If this is done, vacuum relief should be provided to prevent collapse of any equipment as the oil reduces in volume as it cools. A simple way of doing this would be to drill a small hole in the blocking valve gate or ball as shown in Figure A.24.11.6.3(a) or provide a small-diameter bypass pipe as shown in Figure A.24.11.6.3(b).

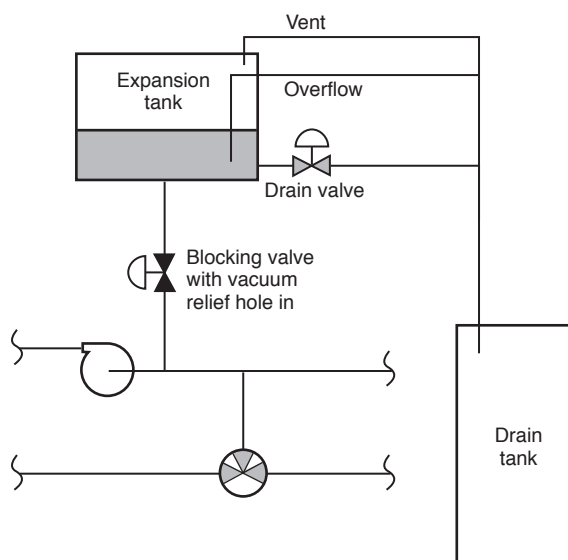


FIGURE A.24.11.6.3(a) Expansion Tank Isolation Using Drain and Blocking Valves.

A.24.11.6.4 A properly maintained thermal oil system should not have oil leaks significant enough to require an automatic oil makeup system. Also, an automatic oil refill system can defeat the purpose of some leak detection systems that monitor the oil level in the expansion tank as a means of detecting an oil leak.

A.24.11.6.5 Nitrogen is the most commonly used inert gas. Nitrogen use will eliminate oxidation and oil degradation that occurs when the hot oil is in contact with air. It also prevents the possibility of an expansion tank explosion should an ignition source find its way into the expansion tank. For these same reasons, inert gas blanketing is recommended for systems operating at lower pressures.

A.24.11.7 The appropriate methods for handling thermal oil depend on the temperature of the oil. When thermal oil is heated to temperatures above its flashpoint, it should be handled as a Class I liquid [flash point < 100°F (37.8°C)]. At intermediate temperatures, it could be appropriate to handle thermal oil as a Class II liquid [100°F (37.8°C) ≤ flash point < 140°F (60°C)]. At normal ambient temperatures, many thermal oils are classified as Class IIIB liquids [flash point ≥ 200°F (93°C)]. The oil manufacturer's Material safety data sheet should be referred to for flashpoint data.

A.24.11.8.1 *Exception No. 1.* Buildings that have dry pipe sprinkler systems can be prone to accidental tripping due to leaking air pressure. This can cause unnecessary shutdown of the thermal oil system. If a fire detection system were also provided, it could be used to actuate the thermal oil isolation interlocks instead of the sprinkler water flow. Trained operator response in accordance with Exception No. 3 is also an alternative to a sprinkler water flow interlock.

Exception No. 2. If, for example, a plant had a thermal oil heated dryer and a thermal oil heated press, high temperature or activation of a water spray system in the dryer would require stopping flow of thermal oil to the dryer, but the press could continue to operate if desired.

Exception No. 3. To meet this exception, operators should have direct visual observation of the affected area or remote visual observation via closed circuit television. Regular training sessions should be held to assure proper operator response, and an emergency shutdown switch should be located in proximity to all operators expected to fulfill the emergency shutdown function.

A.24.11.8.2 Larger plants that have full process control monitoring and alarm annunciation in a constantly attended control room can provide this function in the control room. Other facilities could need one or more emergency shutdown switches more local to the equipment, but the location should not be so close that the switch could not be accessed in a fire emergency.

A.24.11.9.3 Fluidized bed burners and burners that combust wood waste on a grate contain a quantity of unburned fuel during normal operation. They cannot be instantly shut off like a conventional gas, oil, or pulverized fuel suspension burner. During any emergency stop or other shutdown that does not fully combust the bed of fuel, or when thermal oil is leaking into the combustion chamber, combustibles (mostly carbon monoxide with small amounts of hydrogen) will be generated due to the latent heat in the fire box and lack of enough air for complete combustion.

Heaters that exhaust directly into a stack can usually prevent the accumulation of explosive concentrations of combustibles by natural draft means. Some facilities recover additional heat from the thermal oil heater stack gas by ducting the burner exhaust into other utilization equipment. Natural draft is unreliable in these instances, and other means, such as continued operation of the induced draft (ID) fan at minimum speed, automatic-opening emergency vents on the burner exhaust duct, isolation dampers, or inert gas blanketing systems should be used to prevent buildup of explosive concentrations

of combustibles.

Solid fueled burners should be designed per the requirements listed below.

Electrical Classification

The area electrical classification can be general purpose for the handling of Class II liquids [100°F (37.8°C) ≤ flash point < 140°F (60°C)] or Class III liquids [flash point ≥ 140°F (60°C)]. Consideration should be used in locating electrical devices for ease of access and routine maintenance.

Safety System Features

The thermal oil system should be interlocked to isolate major piping segments in the event of a fire or emergency shutdown to limit the largest credible thermal oil spill. The thermal oil system should be interlocked to actuate in a fail-safe manner. The following should be arranged to actuate:

- (1) The supply of heat to the thermal oil system should be shut down (ID fan or fuel supply for gas or suspension burner).
- (2) Safety shutoff valves, bypass valves, and or three-way divert valves of fail-safe design should be actuated to isolate all secondary circulating loops from the primary loop.

An accessible, manual, remote emergency shutoff (zone stop) should be provided that is capable of safely shutting down and isolating the heat transfer system in the configura-

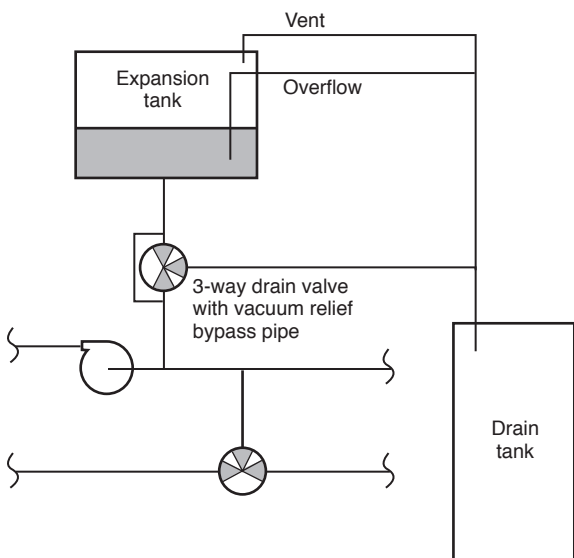


FIGURE A.24.11.6.3(b) Expansion Tank Isolation Using a Three-Way Valve.

tion required to limit the largest credible thermal oil spill. Larger plants that have full process control monitoring and alarm annunciation in a constantly attended control room can provide this function in the control room.

Measuring instrumentation and interlocks should be provided to sound an alarm and automatically shut down the fuel source to the thermal oil heater when any of the safety conditions are detected.

Alarm set point levels should be below or above the auto emergency shutdown levels to monitor the variables and provide an opportunity for operators to correct the problem before conditions reach an emergency shutdown level.

Validation of data should be implemented in the control system to ensure data integrity of all communications and Input/Output (I/O). This validation of input data or communications should use recognized programming method and should include, but not be limited to:

- (1) Rack failure
- (2) Communication loss to remote I/O racks
- (3) Rack power supply failure
- (4) I/O card failure
- (5) Network communication loss
- (6) Network switch failure
- (7) Loss of communications
- (8) Device cable short wire/open wire
- (9) Underrange/Overrange values
- (10) External power supply failure

On failure of any of the above validations the logic should force a trip value into the input data tables for the affected device(s).

The system would then shut down as if a trip condition occurred.

Access to programmed safety logic (if used) should be restricted to prevent accidental changes. No forces or jumpers should be applied to any Programmable Logic Controller (PLC) or hardwired safety thermal oil controlled systems.

Safety System Design

Safety system design should take into consideration, but not be limited to, the following criteria:

- (1) Manufacture of hardware and PLC (Platform)
- (2) Reliability of instrumentation and devices
- (3) Safety device identification
- (4) Validation of information
- (5) Access requirements
- (6) Maintenance and testing
- (7) Segregation of equipment

Safety Interlocks

The thermal oil system should have the following interlocks, which should be programmed or wired for fail-safe application:

- (1) Low thermal oil flow (analog)
- (2) High thermal oil temperature at heater outlet (analog or thermocouple)
- (3) Expansion tank level for low detection (analog)
- (4) Fire zone water flow (discrete)
- (5) High oil differential pressure (analog) (*under evaluation*)
- (6) High temperature at heater inlet (analog or thermocouple)

- (7) Form of system leak detection (optional if rate of change is programmed using expansion tank level)
- (8) Fill and drain tank level (analog)
- (9) Expansion tank temperature (analog)
- (10) Flue gas temperature (analog)
- (11) Thermal oil pumps seal leak detection (discrete)
- (12) Emergency cooling water make-up detection (discrete)

Definitions of Emergency Shutdown/Trip, Alarm, and Warning

Emergency Shutdown/Trip. System is shut down; solid red visual indication; condition must be cleared, and system restarted.

Alarm. Requires operator intervention, PLC can impose some control functionality to mitigate reaching emergency shutdown condition; flashing red visual indication.

Condition can be acknowledged; if condition is not cleared, the indication will be reactivated.

Warning. Indication to operator; can be acknowledged.

Mandatory Safety Interlocks

All trips should be instantaneous and fail-safe conditioned. The following percentages are estimated nominal targets based on normal operating conditions. All conditions, including start-up, cooldown, and mill specifics, need to be taken into consideration for final set points.

Thermal Oil Flow

Trip: Set at 80 percent of design flow

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 95 percent of design flow

Actions: Disable heat modulation and limit all devices producing heat to minimum.

High Heater Outlet Oil Temperature

Trip: Set at 110 percent of design temperature not to exceed 525°F (274°C)

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 105 percent of temperature

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Thermal Oil Expansion Low Tank Level

Trip: Set at 25 percent of tank capacity

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 35 percent of tank capacity

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Fire Zone Water Flow

Trip: Discrete input from measurement devices

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Same as above

High Oil Differential Pressure

Trip: Set at (*under evaluation*) of design or normal pressure

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at (*under evaluation*) of design flow

Actions: Disable heat modulation and limit all devices producing heat to minimum.

High Heater Inlet Oil Temperature

Trip: Set at 110 percent of design temperature not to exceed 525°F (274°C)

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 105 percent of temperature

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Leak Detection Rate of Change

Trip: Set at 110 percent of normal expansion rate

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 105 percent of normal expansion rate

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Emergency Shutdown (Zone Stop)

Trip: Set on activation of stop

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Fill and Drain Tank Level

Trip: Set at 90 percent of tank design level

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 85 percent of tank design level

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Expansion Tank Temperature

Trip: Set at 110 percent of normal tank operating temperature

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 100 percent of normal tank operating temperature

Actions: Disable heat modulation and limit all devices producing heat to minimum.

Flue Gas Temperature

Trip: Set at 115 percent of normal operating temperature

Interlock: Fuel supply, primary loop isolation and bypass valves, emergency cooling

Alarm: Set at 110 percent of normal operating temperature

Actions: Visual alarm indication cannot be reset until condition is cleared.

Circulation Pump Seal Leak

Alarm: Set on detection leak

Actions: Visual alarm indication cannot be reset until condition is cleared.

Emergency Cooling Makeup Water

Warning: Set on detection of water flow

Actions: Warning indication.

Annunciation, Display, and Reset of Emergency Shutdown/Trips, Alarms, and Warnings

Emergency shutdown/trips, alarms and warnings should be clearly displayed to the operator as described below. Each event should be accompanied by an audible/visual event suitable for the environment and be capable of 10 dB above normal ambient noise. The reset pushbutton(s) should be wired to the PLC for resetting of the mandatory alarms as specified above, "Definitions of Emergency Shutdown/Trip, Alarm, and Warning."

(1) Emergency Shutdown/Trips

- (a) The operator should be alerted to the trip in the current HMI display.
- (b) A separate light indication (solid red) should be located in "proximity" to the primary pump room area and inside the main operator console room.
- (c) The operator should be able to acknowledge the audible/visual event; however the condition must be cleared before the system can be reset and the system restarted.

(2) Alarms

- (a) The operator should be alerted to the alarm in the current HMI display.
- (b) A separate light indication (flashing red) should be located in "proximity" to the primary pump room area and inside the main operator console room.
- (c) The operator should be able to acknowledge this audible alert; however, all alarms (as described above, "Definitions of Emergency Shutdown/Trip, Alarm, and Warning") should only be reset by pressing local reset pushbuttons, located close to the equipment (primary room; secondary room; heater area). The alert should reappear after a reasonable time, if the condition still exists.

(3) Warnings

- (a) The operator should be alerted to the warning in the current HMI display.
- (b) The operator should be able to acknowledge the alert via normal actions.

Recording and Logging of Data

Data pertaining to the operation of the thermal oil system should be logged in order to evaluate normal and abnormal operation and performance of the system. The following items constitute the minimum data points required for capture:

- (1) Thermal oil flow
- (2) Primary pump start and stop time
- (3) Heater outlet oil temperature
- (4) Primary pump faults
- (5) Thermal oil expansion tank level
- (6) Secondary pump start and stop time
- (7) Heater outlet oil pressure
- (8) Secondary pump faults
- (9) Heater inlet oil temperature
- (10) Isolation valve positions
- (11) Thermal oil expansion tank level rate of change
- (12) Fixed burner system fuel output (gas or suspension burners)
- (13) Heater outlet air temperature
- (14) All emergency shutdown/trip and alarm conditions
- (15) Primary pump amps bypass valve positions
- (16) Secondary system temperatures (all available)
- (17) Thermal oil fan start and stop time (for bark burner installations)
- (18) Fire protection zone flow switch actuation
- (19) Thermal oil fan faults (for bark burner installations)
- (20) Flue gas temperature
- (21) Alarm reset pushbuttons

All data associated with the above system variables should be captured by Industrial SQL and stored in the facility's manufacturing server.

A.24.11.9.4 This is commonly done using suitable dampers, isolation gates, waste stacks, and/or burner control logic. The control logic should anticipate all possible operating modes of burners on individual pieces of equipment, whether operating singly or together, to ensure safe startup and shutdown under normal or upset conditions.

A.24.11.9.6 An alarm set point should be provided at detection levels earlier than the auto-shutoff levels so as to monitor the variables in 24.11.9.6 and provide an opportunity for operators to correct the problem before conditions reach an unsafe level.

A.24.11.10.4 One major concern in this regard is where thermal oil is used to heat water, such as in log thaw vats common to oriented strand board plants or in steam generators. Water in the thermal oil piping will flash to steam when heated and can cause overflow of the expansion tank or overpressurization in closed systems.

A.24.11.10.5 Typical dangerous scenarios should include all the alarm conditions that result in heater shutdown and isolation of piping and equipment, especially those involving a fire in the area and actions necessary to confirm or stop flow of leaking oil.

A.24.11.10.7 With extended exposure to elevated temperatures and/or air in expansion tanks, thermal oils undergo degradation, which can include oxidation and cracking. This degradation can change oil viscosity, heat transfer properties, flash point, and so forth, making the oil unsuitable for continued service.

A.24.11.11 Due to a loss history showing that thermal oil fires can be very severe and long lasting, it is highly recommended that automatic sprinkler protection be provided throughout all building areas potentially exposed to a thermal oil spill fire.

A.24.11.11.2 A common design for an extinguishing system utilizes a water spray injection system designed on the assumption that all water injected will flash to steam and that the resultant flow of steam will equate to 8 lb (128 kg) per minute per 100 ft³ (2.8 m³) of heater or heat exchanger volume. Some thermal oil heater vendors will supply this kind of extinguishing system as a factory option.

When this option is used, prior to water being injected, the heater forced draft fan damper should be closed and the induced draft fan damper moved to the full-open position. This damper arrangement minimizes natural draft airflow through the heater and could deplete the steam concentration and supply air to the fire while simultaneously providing a path for pressure relief from the rapid volume expansion that occurs when the water mist flashes to steam.

Once temperatures are sufficiently reduced in the heater and the fire is extinguished, the water will no longer flash to steam and can collect in the heater enclosure low points. An allowance for draining water and/or unburned thermal oil to a suitable drainage location should be considered.

Inert gas extinguishing systems (e.g., CO₂ or nitrogen) are sometimes used. Although these systems can rapidly extinguish a fire if the concentration can be established and held, they have very little cooling ability. Hot refractory and internal heater surfaces can remain above the autoignition temperature of the thermal oil for many hours. It is critical that the inert gas supply be able to maintain the required extinguishing concentration long enough for the heater's internal surfaces to cool below the thermal oil autoignition temperature, or reignition will occur.

Automatic operation is preferred. One common way of implementing this is with a high/high temperature alarm (i.e., the first high temperature alarm alerts operators of a malfunction, and a second higher temperature alarm actuates the extinguishing system if operator intervention does not correct the high temperature condition). Another method uses two independent signals to trip the extinguishing system (e.g., a signal indicating loss of thermal oil combined with another signal indicating high temperature or high combustibles in the heater exhaust).

A.24.11.11.3 Some heaters have auxiliary, diesel-driven standby thermal oil circulation pumps that automatically start if the oil pressure is abnormally low, such as from pump failure or power outage. These standby pumps will also need to be disabled to keep them from automatically starting when the primary pumps shut down, unless they are part of the oil circulation system permitted in the exception.

A.24.12.2.1 A detached building for storage is preferred. Venting should be designed in accordance with NFPA 68 and additional guidance can be found in FM Property Loss Prevention Data Sheet 7-76, *Prevention and Mitigation of Combustible Dust Explosion and Fire*. Conventional lightweight, pre-engineered metal panels on steel frame buildings will meet the intent of this recommendation.

A.24.12.2.3 Refer to paragraph 2.4.3 of FM Property Loss Prevention Data Sheet 7-14, *Fire Protection for Chemical Plants*.

A.25.1.1 Examples of industries that handle combustible particulate solids, either as a process material or as a fugitive or nuisance dust, include but are not limited to the following:

- (1) Agricultural, chemical, and food commodities, fibers, and textile materials
- (2) Forest and furniture products industries
- (3) Metals processing
- (4) Paper products
- (5) Pharmaceuticals
- (6) Resource recovery operations (tires, municipal solid waste, metal, paper, or plastic recycling operations)
- (7) Wood, metal, or plastic fabricators

A.25.1.1.2 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 μm . *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.

A.25.7.3.1.3 For many situations, the layer depth method is the easiest and can be used for any application or ceiling height. Either of the mass methods can be used for any ceiling height. Mass method A does not require specific material properties or building strength data. Using mass method A for buildings with greater than 39 ft (12 m) ceiling height does not allow the user increased dust accumulation, compared to mass method B. Mass method B allows the owner/operator the greatest flexibility in addressing dust accumulations and takes into account specific building and material properties. However, this requires more detailed information about the building construction that might not be available for some buildings. When calculating dust loads by either method, include dust on mezzanines. When calculating the allowable volume or mass of dust, the area of the mezzanine is not added to the footprint of the building or room.

A.25.7.3.1.5 In some cases, such as for fine particulates generated from hardwoods, it is advisable to correct for a settled bulk density in excess of the 20 lb/ft³ (320 kg/m³) used in this requirement.

The measurement of bulk density is dependent upon the particle size, shape, and chemical content. Settled bulk density is not the same as tapped bulk density. Settled bulk density is the density as the material has settled in the facility under normal operating conditions. Tapped bulk density is the maximum density that can be achieved without intentional compression. Tapped bulk density measurement numbers are almost always higher than settled bulk density measurement numbers.

Moisture content is a factor that has a profound effect on dust deflagration propagation. Moisture in dust particles raises the minimum ignition temperature (MIT), minimum ignition energy (MIE), and minimum explosible concentration (MEC) by increasing agglomeration of particles.

Moisture content can be determined using the following method:

- (1) Weigh the material of which a moisture content is to be determined in the moist, as-received state.
- (2) Dry the material for 24 hours in a drying oven set at 167°F (75°C).
- (3) Reweigh the sample.

Calculate the moisture content from the following relation:

$$\% \text{ MC} = [(\text{moist weight}) - (\text{dry weight})] (100) / \text{moist weight}$$

While no ASTM method currently exists for determining settled bulk density, the following method has been utilized to produce usable results. Because bulk density measurements are used to determine the permissible dust layer depth for hazard assessment, bulk density should be based on the dried weight, not the moist weight; the water in the moist sample does not add combustible material to the mixture.

Recommended Tools: Neoprene or other similar plastic-type gloves, ruler, two natural bristle brushes [4 in. (100 mm) width], scales (that measure grams), pre-weighed container (weighed in grams to the nearest tenth of a gram), and a drying oven.

Recommended Procedure:

- (1) Pre-weigh and record container weight.
- (2) Locate horizontal surface area where dust is present and evenly distributed across a flat surface. This is an important criterion.
- (3) Mark off a 1 ft² (0.09 m²) area. (It is easier if one of the four sides is the horizontal surface ledge.) If an area 1 ft × 1 ft is not available due to the size of the surface use, ½ ft × 2 ft (0.15 m × 0.6 m) or ¼ ft × 4 ft (0.076 m × 1.2 m).
- (4) Using the ruler as a guide, carefully scrape the other dust surrounding the marked 1 ft² (0.09 m²) (or other established one square foot dimension) away from the dust square (or rectangle) at least 8–12 in. (0.2–0.3 m). Use the first brush if needed to clean dust away from the 1 ft² (0.09 m²) selected for density measurement [ensuring that the 1 ft² (0.09 m²) area does not receive any of the dust being brushed away].
- (5) Measure and record the height [to the nearest ½₃₂ in. (0.8 mm)] of the dust layer as it sits on the horizontal layer. Take a minimum of three to five measurements along the edge of the dust layer to establish an average height [to the nearest ½₃₂ in. (0.8 mm)] of the dust layer.
- (6) Take the second clean, natural bristle brush and carefully brush the dust contained inside the 1 ft² (0.09 m²) area into the pre-weighed container.
- (7) Dry dust sample as outlined above.
- (8) Weigh the dried dust sample and the container together and record the weight in grams.
- (9) Subtract the weight of the container from the weight of the dried dust-filled container to obtain the weight of the dried dust in grams. Record the dust weight.
- (10) Calculate the volume of the dust layer using the average height measured (in inches) × length (12 in.) × height (12 in.) to obtain cubic inches of volume.
- (11) Convert cubic inches to cubic feet.
- (12) Convert grams of dust measured to pounds. (Note: 453.6 g = 1 lb).
- (13) Divide pounds of dust by cubic feet to establish estimated density in pounds per cubic feet (lb/ft³).

Example:

Container pre-weight is 500 g.

Average dust height measured is $2\frac{1}{32}$ in.

Container plus dust weight is 660 g.

Determination of Dust Volume (ft³)

- (1) $2\frac{1}{32}$ in. = $\frac{65}{32}$ in., or 2.03125 in.
- (2) Volume (in.³) = L × W × H = 12 in. × 12 in. × 2.03125 in. = 292.5 in.³
- (3) Convert cubic inches to cubic feet. There are 1728 in.³ in 1 ft³.
- (4) Volume (ft³) = Volume (in.³) ÷ 1728 = 292.5 ÷ 1728 = 0.169 ft³ (0.0048 m³)
- (5) (305 mm × 305 mm × 51.6 mm) = (0.305 m × 0.305 m × 0.0516 m = 0.0048 m³)

Determination of Dust Weight (lb)

To obtain the weight of the dust, subtract the container weight in grams from the weight of the container containing the dried sample:

- (1) 660 g – 500 g = 160 g
- (2) Convert grams to pounds. There are 453.6 g in 1 lb, therefore: 160 g ÷ 453.6 g/lb = 0.353 lb (of dust)

Determination of Dust Density

- (1) Divide pounds of dust by volume of dust in cubic feet: 0.353 lb ÷ 0.169 ft³ = 2.087 lb/ft³
- (2) Round off to nearest tenth of a pound = 2.1 lb/ft³: [0.16 kg ÷ 0.0048 m³] (33.43 kg/m³)

A.25.7.3.5 See Annex S for example calculations applying the layer depth criterion method.

A.25.7.3.5.2 See Section S.2 for example of how to apply this method.

A.25.7.3.6 Mass per unit area derived from these mass determination methods can be used to derive a measurable layer depth using the fact that mass divided by settled bulk density equals layer depth. See Section S.3 for an example of how to apply this method.

Because fugitive dust could accumulate in a localized area of the building or room (localized area less than 10 percent of the total floor area), the floor area limit (A_{floor}) used in the equations in 25.7.3.6.1 or 25.7.3.6.2 has been set to 2000 m². For an example of the calculation of threshold dust mass, see Annex S.

A.25.7.3.7 See Section S.3 for an example of how to apply this method.

A.25.7.3.7.1 The dust explosion hazard area equation in 25.7.3.7.1 originates from the partial volume equation in NFPA 68 which adjusts the amount of venting needed when the design scenario presumes the combustible mixture fills only a part of the enclosure. NFPA 68 uses the ratio of P_{red} to P_{max} and the fill fraction to make this adjustment. P_{red} is the maximum pressure predicted to be developed during a vented deflagration and should be less than the strength of the weakest building structural element not intended to vent or fail. Windows, for instance, might be intended to fail. NFPA 68 sets an upper bound for P_{red} , ensuring that the calculated pressure during the event does not exceed the strength of the enclosure. This upper bound is P_{es}/DLF , the dynamic strength of the weakest

building structural element not intended to vent or fail. In the implementation here, the goal is to see if any deflagration venting is needed to prevent damage to the main building structural components; thus, P_{red} is equated to its maximum allowable value, based on the building/room design.

In a deflagration, the pressure that is developed changes with the dust concentration. The equation in 25.7.3.7.1 uses the so-called worst case concentration of dust in a combustible mixture, C_{up} , as defined in NFPA 68. A conservative way to evaluate the pressure attained at lower average dust concentration is to assume that all of the dust available is concentrated in a smaller volume than the worst case concentration. This smaller volume is a fraction of the total volume, the fill fraction. In the equation in 25.7.3.7.1, the threshold dust mass, M_{exp} , divided by the product of worst case concentration and building volume is the fill fraction. When the accumulated dust mass is larger than the threshold for the explosion hazard, then the fill fraction is greater than the ratio of P_{es}/DLF to P_{max} and an explosion hazard exists.

A.25.7.3.7.1.2 See Ural, “Towards Estimating Entrainment Fraction for Dust Layers.” See NFPA 68 for additional information.

A.25.7.3.7.2 The dust flash fire hazard area equation in 25.7.3.7.2 estimates the fraction of the volume that could be filled by an expanded fireball from burning dust. The room or building volume up to person height is taken as the total volume for this hazard, regardless of actual building height. The threshold for the flash fire hazard is based on allowing the accumulated dust mass to reach the worst case concentration in an unburnt volume, which, when expanded in a fireball, is only a fraction of the volume described by the product of person height and floor area. The relation in 25.7.3.7.2 uses as its risk tolerance criterion the probability (p) of an occupant being in the same location as the deflagration flame. This choice implies that some residual risk remains.

A.25.7.3.7.2.1 See Ural, “Towards Estimating Entrainment Fraction for Dust Layers.” See NFPA 68 for additional information.

A.25.7.3.8 The risk assessment method in 25.7.3.8 supplements the DHA required in Chapter 7 and Section 25.7. It is intended to focus on material properties and inherent design features of the equipment and the facility necessary to determine the extent of the hazard areas.

A.25.8.4.6.1 Unscheduled housekeeping should be performed in accordance with Table A.25.8.4.6.1(a) to limit the time that a local spill or short-term accumulation of dust is allowed to remain before the local area is cleaned to less than the threshold dust mass/accumulation.

Table A.25.8.4.6.1(b) shows approximate equivalent depths for the accumulation values in Table A.25.8.4.6.1(a) when the threshold dust mass/accumulation is 0.2 lb/ft² (1 kg/m²). The owner/operator can use an approximate depth to facilitate communication of housekeeping needs.

A.25.8.4.6.2 Where the facility is intended to be operated with more than the dust accumulation defined by the owner/operator's chosen criterion in 25.7.3, additional protective measures are necessary. This is a concept similar to the maximum allowable quantities established in the building codes.

Table A.25.8.4.6.1(a) Unscheduled Housekeeping

Accumulation on the Worst Single Square Meter of Surface	Longest Time to Complete Unscheduled Local Cleaning of Floor- Accessible Surfaces	Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces
>1 to 2 times threshold dust mass/ accumulation	8 hours	24 hours
>2 to 4 times threshold dust mass/ accumulation	4 hours	12 hours
>4 times threshold dust mass/ accumulation	1 hour	3 hours

Table A.25.8.4.6.1(b) Unscheduled Housekeeping Accumulations

Accumulation on the Worst Single Square Meter of Surface	Average Depth at 75 lb/ft ³ (1200 kg/m ³)	Average Depth at 30 lb/ft ³ (481 kg/m ³)
>0.2–0.4 lb/ft ² (>1 to 2 kg/m ²)	> $\frac{1}{32}$ – $\frac{1}{16}$ in. (0.8–1.7 mm)	> $\frac{5}{64}$ – $\frac{5}{32}$ in. (2.1–4.2 mm)
>0.4–0.8 lb/ft ² (>2 to 4 kg/m ²)	> $\frac{1}{16}$ – $\frac{1}{8}$ in. (1.7–3.3 mm)	> $\frac{5}{32}$ – $\frac{5}{16}$ in. (4.2–8.3 mm)
>0.8 lb/ft ² (>4 kg/m ²)	> $\frac{1}{8}$ in. (>3.3 mm)	> $\frac{5}{16}$ in. (>8.3 mm)

A.25.8.7.2.2.4 Periodic cleaning of components is especially important if the blower or fan is exposed to heated air.

A.25.8.7.2.2.5 If rust is allowed to form on the interior steel surfaces, it is only a matter of time before an iron oxide (rust) becomes dislodged and is taken downstream, striking against the duct walls. In some cases, this condition could cause an ignition of combustibles within the duct. The situation worsens if aluminum paint is used. If the aluminum flakes off or is struck by a foreign object, the heat of impact could be sufficient to cause the aluminum particle to ignite, thereby initiating a fire downstream.

A.25.8.7.2.5.3 For information on maintenance of deflagration venting, see NFPA 68.

A.25.8.7.3.1 Impairments can include isolating of fire pump controllers, closing of sprinkler system control valves, and isolating and disabling or disconnecting of detection, notification, and suppression systems.

A.25.8.7.3.2 The impairment procedure consists of identifying the impaired system and alerting plant personnel that the protection system is out of service.

A.25.8.7.3.3 The facility manager is responsible for ensuring that the condition causing the impairment is promptly corrected.

A.25.8.7.3.4 When the impairment notification procedure is used, it provides for follow-up by the relevant AHJs. This follow-up helps to ensure that impaired fire and explosion protection systems are not forgotten. When the system is closed and reopened, most companies notify their insurance company, their broker, or the AHJ by telephone or other predetermined method.

A.25.8.9 With regards to 8.9.2, qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps and professional licenses.

A.25.8.9.3 With regards to 8.9.3.4, 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.

A.25.9.3.1.2 The use of loadbearing walls should be avoided to prevent structural collapse should an explosion occur.

A.25.9.3.2.2.2 An appropriate test method is in accordance with NFPA 252.

A.25.9.3.2.4 The design of deflagration venting should be based on information contained in NFPA 68.

A.25.9.3.2.4.1 The need for building deflagration venting is a function of equipment design, particle size, deflagration characteristics of the dust, and housekeeping requirements. As a rule, deflagration venting is recommended unless there can be reasonable assurance that hazardous quantities of combustible and dispersible dusts will not be permitted to accumulate outside of equipment.

Where building deflagration venting is needed, detaching the operation to an open structure or to a building of damage-limiting construction is the preferred method of protection. Damage-limiting construction involves a room or building that is designed such that certain interior walls are pressure resistant (can withstand the pressure of the deflagration) to protect the occupancy on the other side and some exterior wall areas are pressure relieving to provide deflagration venting. It is preferable to make maximum use of exterior walls as pressure-relieving walls (as well as the roof wherever practical), rather than to provide the minimum recommended. Further information on this subject can be found in NFPA 68.

deflagration venting closures should be designed such that, once opened, they remain open to prevent failure from the vacuum following the pressure wave.

A.25.9.3.2.4.2 For further information on restraining vent closures and fireball impingement areas, see NFPA 68.

A.25.9.3.3.2 This provision requires shorter travel distances and wider egress pathways, resulting in shorter egress times for those occupancies with high hazard contents. In many cases, it also requires multiple means of egress so that occupants do not have to travel past a hazardous situation while evacuating the facility.

A.25.9.3.5.2.1 ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, is a typical test method used. Equivalent test methods can also be used.

A.25.9.3.5.3.1 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. Such a dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist. (See Annex S.)

A.25.9.4.1 The following items describe areas of concern during the design and installation of process equipment:

- (1) The elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth
- (2) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and of the building or room
- (3) The proper classification of electrical equipment for the area and condition
- (4) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings
- (5) The use of electrically conductive belting, low-speed belts, and short center drives as a means of reducing static electricity accumulation (See 9.4.3.)
- (6) Power transmitted by belt, chain, or shaft as follows:
 - (a) For power transmitted to apparatus within the processing room by belt or chain, a nearly dusttight enclosure of the belt or chain constructed of substantial noncombustible material that should be maintained under positive air pressure
 - (b) For power transmitted by means of shafts, shafts that pass through close-fitting shaft holes in walls or partitions

A.25.9.4.1.3 These devices reduce the frequency or likelihood that the sparks will cause a deflagration but do not eliminate the need for deflagration isolation devices. The abort gate cannot be relied on to serve as a deflagration isolation device because the response time is relatively slow and construction is usually unsuitable for withstanding explosion pressures.

Additional information on spark extinguishing systems can be found in Annex R.

A.25.9.4.3.1.3 For additional information, see ASTM E2012, *Standard Guide for the Preparation of a Binary Chemical Compatibility Chart*.

A.25.9.4.3.2 Except for inerted systems, it is preferable to design systems that handle combustible particulate solids to operate under negative pressure. Negative pressure (i.e., vacuum) pneumatic conveying systems will not leak dust from duct/piping connections, and so forth, due to the vacuum (air comes in rather than out). Closed loop inert gas systems commonly use pressure differential for conveying the material and require only a small amount of make-up inerting gas to operate.

A.25.9.4.3.3.2 The exclusion of explosion isolation on branch ducts from individual pieces of equipment or interconnected equipment addresses the propagation from the equipment through the ductwork and to the other interconnected equipment (or between portions of the single piece of equipment). It does not address any required explosion isolation on the process flow streams between those pieces of equipment. This exclusion does not apply to the requirements for explosion isolation to protect those pieces of equipment from a deflagration in the AMS, propagating upstream through the dust collection ductwork.

Most dust collection systems operate with sufficient airflow to keep the environment within the connected equipment below the MEC, thereby reducing the risk of explosion originating in those pieces of equipment.

Figure A.25.9.4.3.3.2 is an illustration of a manifolded system with isolation of a branch duct.

A.25.9.4.4.1.1 The committee recognizes the hazard of media failure and effect on electrical equipment. For a combustible dust, this would be a Class II, Division 2 or Zone 22 location. For a hybrid mixture, a Class I, Division 2 or Zone 2 would additionally be necessary.

A.25.9.4.4.5 Enclosureless dust collectors are not meant for use with most dusts created during the venting of process equipment or other aerated dust sources. Fine dust will rapidly blind the filter, which results in reduced performance and a significant increase in deflagration hazards associated with the system operation and performance.

Protection required in accordance with NFPA 68 and/or NFPA 69

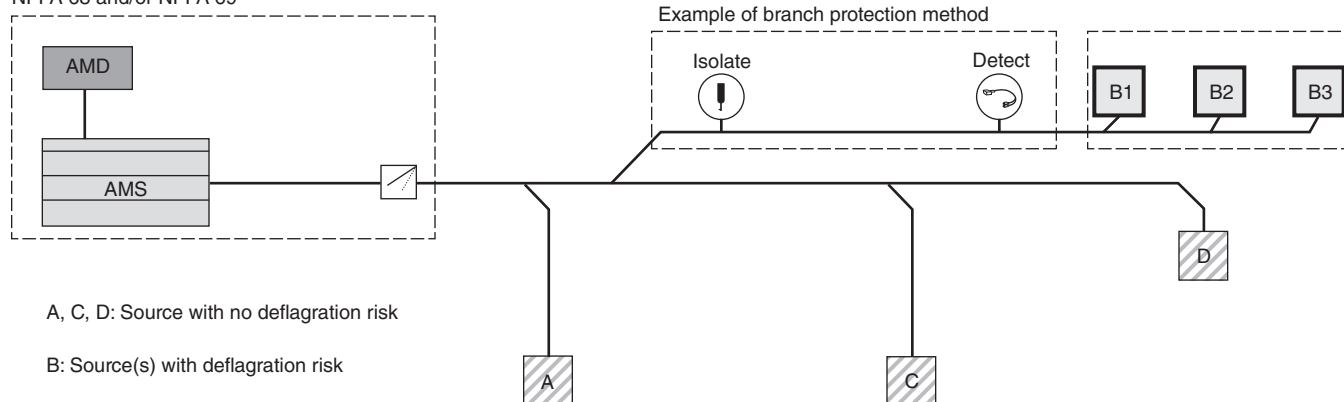


FIGURE A.25.9.4.3.3.2 Manifolded System with Isolation of a Branch Duct.

A.25.9.4.4.5(4) Many of the enclosureless dust collectors are manifolded into multiple bags with containers. The 5000 cfm (2.4 m³/sec) limit refers to the overall airflow through the assembly and not just to a single bag with collected material container.

A.25.9.4.4.5(5) *NFPA 70*, in 502.125(B), states: "In Class II, Division 2, locations, motors, generators, and other rotating electrical equipment shall be totally enclosed non ventilated, totally enclosed pipe-ventilated, totally enclosed water-air-cooled, totally enclosed fan-cooled or dust-ignition proof for which maximum full-load external temperature shall be in accordance with 500.8(D)(2) [of *NFPA 70*] for normal operation when operating in free air (not dust blanketed) and shall have no external openings." *NFPA 70* does not include an equivalent description of suitable zone-related equipment.

A.25.9.4.4.5(8) Enclosureless dust collectors are often manifolded into multiple bags (with collected material containers). Each such manifolded assembly must be separated by the required 20 ft or 6.1 m.

A.25.9.4.4.5(9) MIE is determined by testing the material as received with respect to particle size.

A.25.9.4.4.6.1 Presently a standard test method does not exist to provide listing or certification for this type of device for this purpose. The prohibition is being retained until there is listing by a nationally recognized testing laboratory or proof this type of device can be used successfully for this purpose.

Currently there are strong concerns regarding the differential pressure effects, material accumulation effects, and so forth, which could lead to problems that represent additional, uncontrolled or unmitigated hazards.

A.25.9.4.4.7.1 See *NFPA 68*.

A.25.9.4.5 With regards to 9.4.5.2, the Technical Committee on Handling and Conveying of Dusts, Vapors, and Gases is aware of installations of AMDs (electrical motor and impeller) inside the clean-air plenum of AMSs. Standard duty AMDs are not suitable for such service. Because of the potential for failure of the filter medium or other malfunction, the clean-air side of air-material separators should be considered as at least a Class II, Division 2 or Zone 22 location with regard to proper installation of electrical equipment. *NFPA 91* also addresses AMD materials of construction and clearances, including specific requirements where combustible materials could be present.

A.25.9.4.5.1 Some systems are designed to operate at solids concentrations that pose no fire or deflagration risk. Such systems include nuisance dust exhaust systems and the downstream side of the last AMS in the pneumatic conveying system.

A threshold concentration limit of 10 percent of the MEC has been set to discriminate between such systems and other systems designed to operate at a significant combustible solid loading. This limit ensures that normal variations in processing conditions do not result in the combustible particulate or hybrid mixture concentration approaching the MEC.

A.25.9.4.6.2 Where flexible hoses are used, they should be of the minimum length to accommodate the intended function. Most flexible hoses produce large pressure drops per unit of length, reducing efficiency.

A.25.9.4.8 Abort gates cannot be relied upon to manage deflagrations. See also Annex R.

A.25.9.4.8.1 With regards to 9.4.8.1.3, the abort gate should be a high-speed device with a combined reaction time, including detection and closure, of less than 500 milliseconds.

A.25.9.4.9.2 See A.9.4.9.2.

A.25.9.4.9.5 For information on designing deflagration venting, see *NFPA 68*.

A.25.9.4.9.6.3 See A.9.4.9.3.2(2).

A.25.9.4.11.3 As a practical matter, screens are difficult to protect against explosion by deflagration venting or inerting. Therefore, it is important that screens be isolated from the fire and explosion hazards of the remainder of the process and be adequately protected against electrostatic ignition sources. Protection should be accomplished by bonding and grounding of all conductive components.

A.25.9.4.12.2 For information on deflagration pressure relief, see *NFPA 68*.

A.25.9.4.13 Possible protection methods could include but not be limited to the following:

- (1) Zero speed switches
- (2) Flow indicators
- (3) Level probes
- (4) Heat sensors
- (5) Dust level sensors
- (6) Mechanical feeding devices equipped with a shear pin or overload detection device and alarm.
- (7) An alarm sounding at the operator control station.
- (8) Direct connection of drives used in conjunction with feeders, air locks, and other material feeding devices
- (9) 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
- (10) Operator training regarding proper operation and protection methods
- (11) Maintenance training regarding proper operation and protection methods

A.25.9.4.14 Examples of bucket elevators can be Z conveyors, open bucket elevators, enclosed bucket elevators, and angled bucket elevators.

A.25.9.4.14.2 Access doors should be dusttight. Pits should be lighted and accessible and should provide ample room for cleaning, lubrication, repairs, and replacement of parts. Elevator boot sections and the spouts feeding them should be constructed so as to minimize choking of the boot.

A.25.9.4.14.4 Any motor or combination of motors utilized should be no larger than the smallest standard motor(s) capable of meeting this requirement.

A.25.9.4.14.5 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.

A.25.9.4.14.6 A static dissipative or conductive impact surface should be utilized to reduce electrostatic charge accumulation.

A.25.9.4.14.12 Not all bucket elevator operations are the same, and a DHA can be used to evaluate whether monitoring

is required. The size, speed, type of material, presence of ignition sources, and amount of dust generated in the elevator should be taken into consideration in this evaluation. Smaller, slower bucket elevators that generate insufficient concentrations of combustible dust might not require monitoring.

A.25.9.4.15 Explosion protection should be provided when the risk is significant. Where coverings are provided on clean-out, inspection, or other openings, they should be designed to withstand the expected deflagration pressure. (See 25.9.8.2.) Examples of enclosed conveyors include screw conveyors, drag conveyors, and chain conveyors.

A.25.9.4.15.2.1 Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature.

A.25.9.4.16 Examples of mixers and blenders include in-line, continuous, batch, agitator, traveling-screw, ribbon blenders, etc.

A.25.9.4.16.2 Typical methods include magnets, screens, or other methods of detection or classification and that could occur in upstream processes.

A.25.9.4.17 See 25.9.6.15 for heating systems.

A.25.9.4.20.1 Ultrafine particles are produced either as part of a process or as a by-product of other process operations such as milling, grinding, polishing, pneumatic conveying, and so forth. Due to the extremely small particle sizes involved, such combustible dust particles represent hazards and material control problems that might not be fully covered by the various NFPA standards on combustible dusts.

This section is provided to assist the user in understanding the possible additional hazards created by the very small particle sizes involved. Currently there is limited information on the effects of extremely small particle sizes on the combustibility and/or explosivity of the combustible dust when compared to the larger particle sizes. In some cases there might be significant differences, and in others no significant difference can be determined.

Due to the extremely small particle sizes involved, many of the typical systems used for particle control (e.g., dust collectors, filters) will not be effective. When a significant fraction of ultrafine particles is present such hazards should be considered.

A.25.9.4.20.3 Due to the extremely small particle sizes involved, the process and material control equipment used in a system might not provide the needed dust control and/or containment normally expected. A typical example would be an AMS. A typical AMS might not be able to provide efficient control of particles less than 0.5 μm (500 nm), thus allowing such particles to escape filtration. If sufficient amounts of these smaller particles are allowed to accumulate in an area they can represent a significant hazard. Any DHA should consider the unique problems associated with effectively handling such particles.

A.25.9.4.20.5.1 Processes used to produce ultrafine particles typically have specific hazards associated with the actual process. These processes are often unique to the process used to create the ultrafine particle. Such hazards should be considered along with the inherent hazards of the ultrafine particle.

A.25.9.6.4 Consideration should be given to the potential for overheating caused by dust entry into bearings. Bearings should be located outside the combustible dust stream, where they are less exposed to dust and more accessible for inspection and service. Where bearings are in contact with the particulate solids stream, sealed or purged bearings are preferred.

A.25.9.6.6.1 Bonding minimizes the potential difference between conductive objects. Grounding minimizes the potential difference between objects and ground.

Subsection 9.6.6.1.1 refers to the fixed equipment and internals and does not include portable containers or packaging being filled or emptied.

A.25.9.6.6.2.1 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 m³.

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.25.9.6.6.2.1(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.25.9.6.6.2.1(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.25.9.6.6.2.2 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.25.9.6.6.2.2(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.25.9.6.6.2.2(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.25.9.6.6.2.3 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.25.9.6.6.5 Electrostatic charge generation on power transmission belts occurs due to contact and separation between the belt and pulleys and is dependent on the width of the belt, speed of rotation, and belt tension. IEC TS 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance*, provides detailed requirements based on belt speed and hazard area classification. It does not require static-dissipative belts in Zone 2 (Class I Division 2) or Zone 22 (Class II Division 2) areas, unless experience shows that incendive discharges occur frequently. The resistance is measured at the inner side of the mounted transmission belt, between an electrode halfway between the two pulleys and ground.

A.25.9.6.6.6 Where a hose has a conductive, spiral reinforcing wire, the wire should be bonded to any conductive component(s) at the end(s).

A.25.9.6.6.9 See NFPA 77 for recommended practices on manual additions of solids into vessels containing flammable atmospheres, including recommended practices on the grounding of personnel.

A.25.9.6.6.9.1 For example, metal chimes on fiber drums should be grounded. For uncoated fiber drums, grounding one chime might be sufficient. Where contact with a grounded operator is used to ground the container (such as with static-dissipative bags), it is important that gloves, if used, be static-dissipative and free of contaminants.

A.25.9.6.6.9.4 Examples of auxiliary loading devices include shovels, scoops, and funnels. Conductive tools can be grounded through a properly grounded operator. See also A.25.9.6.6.9.1 for guidance related to grounding of containers.

A.25.9.6.6.9.5 Where static-dissipative footwear is used for personnel grounding, the floor resistance to ground should be between 10^6 and 10^9 ohms. Care should be taken to ensure that deposits, residues, and coatings that build up over time do not impair grounding between the floor and personnel.

A.25.9.6.6.9.7 A risk assessment should address considerations such as container construction, properties of the solids, properties of the liquid, addition rate, material construction of the receiving vessel, agitating devices, and intensity of agitation. The risk assessment should identify the necessary engineering and administrative controls to ensure that the potential charge accumulation during dumping of the contents will not produce a discharge that exceeds the MIE of the flammable atmosphere within the vessel.

A.25.9.6.11 See 9.6.11 for foreign material removal requirements. Specific attention should be paid to combustible particulate solids where they are introduced into the process stream. Some sources of particulates could include stone, tramp iron, other metallic contaminants, and already burning material. Before a risk management strategy is adopted, both the particulate and the process equipment have to be carefully evaluated.

See Figure A.25.9.6.11(a) and Figure A.25.9.6.11(b) for examples of foreign material removal.

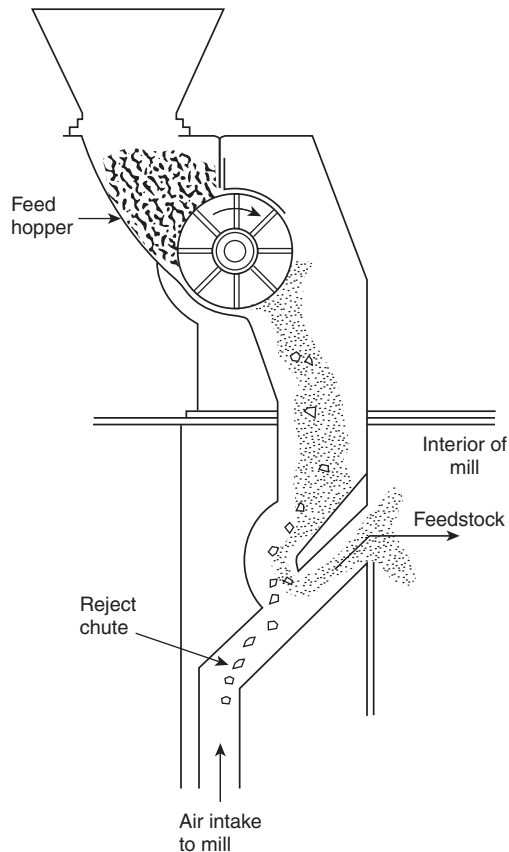


FIGURE A.25.9.6.11(a) Pneumatic Separator.

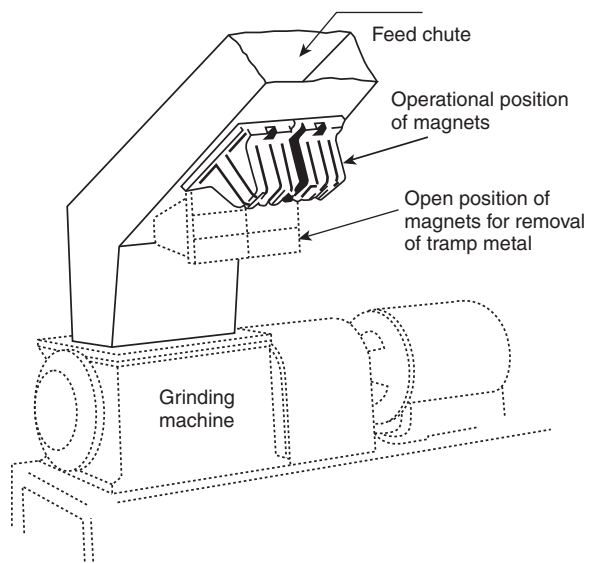


FIGURE A.25.9.6.11(b) Magnetic Separator.

A.25.9.6.11.2 If the particulate particle size range includes dusts that can attain concentrations capable of propagating a flame front through a fuel–air mixture, the risk management options in 25.9.6.11.2 and 25.9.6.11.3 are appropriate. Conversely, if the analysis indicates that the particle size and concentration do not predict a propagating flame front through the fuel–air mixture, the fire protection methods in Section 9.9 should be considered. Certain materials that can self-heat to ignition require means to minimize the hazard. It is permitted to utilize, but not limited to, methods such as mechanically disturbing the material to interrupt the chemical reaction, inerting any equipment containing self-heating materials, reducing moisture content to stop the chemical reaction, or reducing the mass of the material.

A.25.9.6.11.4 Transmission of power by direct drive should be used, where possible, in preference to belt or chain drives.

A.25.9.6.14.2 Refer to NFPA 499. See also Table A.25.9.6.14.2.

Threshold dust accumulation that would require electrically classified equipment is tied to the likelihood of the accumulations and the housekeeping policy as shown in Table A.25.9.6.14.2 provided as guidance. Dust accumulations present hazards due to potential overheating and failure of the covered equipment or overheating of the dust layer resulting in a fire, as well as potential to be put into suspension as a cloud resulting in a flash fire or explosion. However, neither *NFPA 70* nor Chapter 25 provides a mandatory prescription for the user to decide how much dust accumulation should trigger the use of classified equipment.

The likelihood of a dust to be heated to ignition temperature when accumulated on the outside of an electrical enclosure or a piece of electrical equipment is a function of the thickness, thermal conductivity, density, and combustion chemistry of the dust layer as well as the fractional coverage of the equipment's heat dissipation area and the time it remains on the heated equipment.

Both Chapter 25 and NFPA 499 recognize early ignition possibilities due to dehydration and carbonization phenomena but do not offer any methods to evaluate this potential. The appropriate electrical equipment for a given dust is that equipment designed with a maximum surface temperature, designated by the T-code, less than the lower of the layer or cloud ignition temperature of the specific dust. The layer ignition temperature can be determined according to ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*, using at least a ½ in. (13 mm) layer thickness. This is greater than the ⅛ in. (3.0 mm) nominal dust layer establishing a Division 1 or Zone 20 or 21 hazardous (classified) location per NFPA 499, thus providing a safety factor. NFPA 499 also establishes that a Division 2 or Zone 22 hazardous (classified) location would exist when the dust layer prevents clearly discerning the underlying floor color. Given that dust layers tend to be thicker on the upward-facing surfaces of equipment while heat dissipation area is more evenly distributed, it can be seen that this is a significantly conservative approach.

A.25.9.6.15.1 Heating by indirect means is less hazardous than by direct means and is therefore preferred. Improved protection can be provided for direct-fired dryers by providing an approved automatic spark detection and extinguishing system.

Table A.25.9.6.14.2 Guidance for Area Electrical Classification

Depth of Dust Accumulation (in.)	Frequency	Housekeeping Requirement	Area Electrical Classification
Negligible ^a	N/A	N/A	Unclassified (general purpose)
Negligible to <1/32 ^b	Infrequent ^c	Clean up during same shift.	Unclassified (general purpose)
Negligible to <1/32 ^b	Continuous/frequent ^d	Clean as necessary to maintain an average accumulation below 1/64 in. ^e	Unclassified; however, electrical enclosures should be dusttight ^{f,g}
1/32 to 1/8	Infrequent ^c	Clean up during same shift	Unclassified; however, electrical enclosures should be dusttight ^{f,g}
1/32 to 1/8	Continuous/frequent ^d	Clean as necessary to maintain an average accumulation below 1/16 in.	Class II or Class III, Division 2 or Zone 22
>1/8 ^h	Infrequent ^c	Immediately shut down and clean.	Class II or Class III, Division 2 or Zone 22
>1/8 ^h	Continuous/frequent ^d	Clean at frequency appropriate to minimize accumulation.	Class II or Class III, Division 1 or Zone 20 or 21

For SI units, 1 in. = 25.4 mm.

Note: Where the combustible material is anticipated to be solely combustible fibers/flyings, installation in accordance with Class III or Zone Group IIIA is suitable. Where the combustible material is anticipated to be either combustible dust with particle size less than 500 µm or a mixture with combustible fibers/flyings, installation in accordance with Class II or Zone Group IIIB is appropriate.

^aSurface color just discernible under the dust layer.

^b1/32 in. is approximately the thickness of a typical paper clip.

^cEpisodic release of dust occurring not more than about two or three times per year.

^dEpisodic release of dust occurring more than about three times per year or continuous release resulting in stated accumulation occurring in approximately a 24-hour period.

^eIt has been observed that a thickness of about 1/64 in. of a low-density dust is sufficient to yield a small puffy cloud with each footstep.

^fEnclosure Types 3, 3S, 3SX, 4, 4X, 5, 6, 6P, 12, 12K, and 13, per ANSI/NEMA 250, *Enclosures for Electrical Equipment*, are considered dusttight and suitable for use in unclassified locations and in Class II, Division 2; Class III; and Zone 22 hazardous (classified) locations.

^gGuidance to be applied for existing facilities. For new facilities, it is recommended that the electrical classification be at least Class II or Class III, depending on the material form, Division 2 or Zone 22.

^hNFPA 499 recommends immediate shutdown if dust accumulation on electrical equipment exceeds the ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers*, layer ignition temperature thickness test value (typically 1/2 in.).

A.25.9.8.2.1(5) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A.25.9.8.2.1(6) For information on dust retention and flame-arresting devices, see NFPA 68, Section 9.7.

A.25.9.8.2.2 The maximum allowable concentration of oxygen is very dependent on the material, its chemical composition, and, in the case of particulate solids, the particle sizes. In many cases, oxygen concentration reduction systems are designed without a minimum limit on oxygen concentration. However, for some materials, oxygen is required to control chemical reactions. For example, with many combustible metals, it is not advisable to completely eliminate oxygen from the transport gas. During transport, particles can be abraded and broken, exposing unoxidized metal (virgin metal) to the transport gas. When that metal is finally exposed to oxygen-containing air, the rapid oxidation of the virgin metal could produce sufficient heat to ignite the material. It is, therefore, preferable to provide for a low concentration of oxygen in the transport gas stream to ensure the oxidation of virgin metal as it is exposed during the course of transport. Also, some level of oxygen is necessary for the desired solid state polymerization of certain nanoparticles.

A.25.9.8.3 Methods of explosion protection that use containment, venting, and suppression protect the specific process equipment on which they are installed. For details on deflagration propagation, see Annex T.

Exposures of concern include, but are not limited to, bagging operations and hand-dumping operations in which the discharge of a fireball from the pickup point endangers personnel. A common example for the application of such isolation would be in the upstream ductwork associated with a dust collection system servicing a work area. Loading chutes less than 10 ft (3 m) in length and designed for gravity flow are not considered ductwork.

A.25.9.10.2 The design basis generally includes, but is not limited to, the general scope of work, design criteria, process description, material flow diagrams, basis for deflagration protection, basis for fire protection systems, and the physical and chemical properties of the process materials. The design generally includes, but is not limited to, equipment layouts, detailed mechanical drawings, specifications, supporting engineering calculations, and process and instrumentation diagrams.

Annex B Dust Hazards Analysis — Example (CMD-FUN)

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

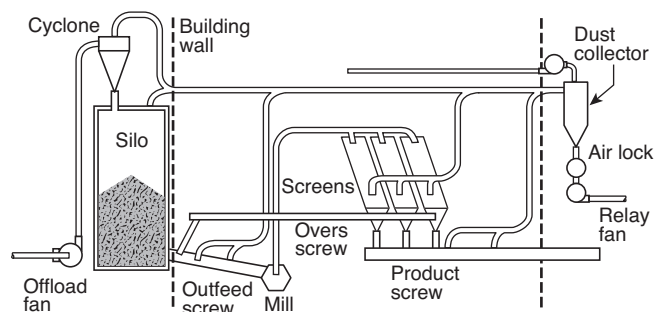


FIGURE B.4.1 An Example Process. (Source: J. M. Cholin Consultants, Inc.)

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 ft³ (0.2 m³) 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 ft³ (0.2 m³) enclosure will yield a fireball volume of approximately 64 ft³ (1.8 m³), 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 ft³ (0.2 m³), it should be documented as such in the DHA.

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 μ m 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 μ m. 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.

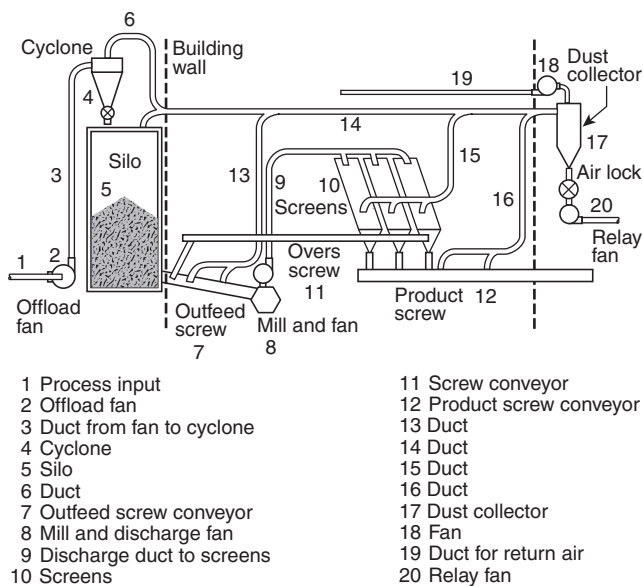


FIGURE B.4.5 An Example Process. (Source: J. M. Cholin Consultants, Inc.)

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 ignition sources 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 ignition sources 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 ignition sources 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

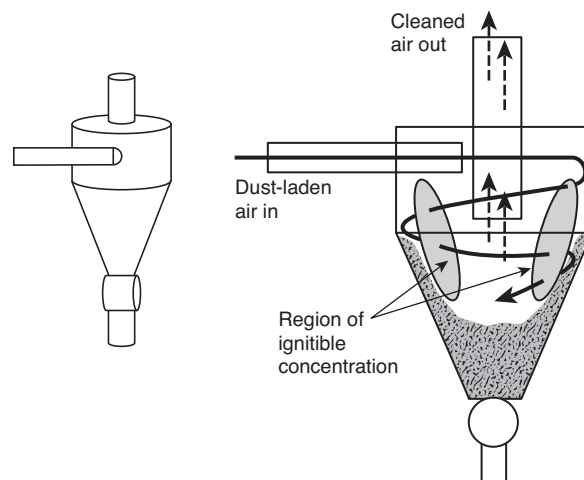


FIGURE B.4.5.4 The Operating Cyclone in Cross-Section.
(Source: J. M. Cholin Consultants, Inc.)

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 ignition sources available? Yes. All of the ignition sources identified in the earlier portions of the system will be sending the ignited particulate to the cyclone. Therefore, there is no alternative but to consider the cyclone an explosion hazard — all four necessary criteria for a deflagration are satisfied in the cyclone.

B.4.5.4.5 What hazard management is in place? The cyclone should be equipped with deflagration hazard management. This usually takes the form of venting and isolation but might also take the form of deflagration suppression and isolation. It is possible that the rotary air lock at the base of the cyclone is sufficient to serve as an isolation device.

If the system is shut down and there is burning material in the hopper section (base) of the cyclone, how is that managed? Most explosions result from deflagrations that are initiated by ongoing fires. Is there any fire detection in place? What is the plan if a fire is detected? (Dumping burning material into a silo is not an option.)

B.4.5.5 Location 5: Storage Silo. Every storage vessel is a particle size separator. When a mixture of material is dumped into a silo, bin, bunker, and so forth, the large particulate falls rapidly to the bottom of the vessel while the fines are lifted up by the air being displaced by the large particulate. This creates a cloud of fine dust in the ullage space, above the settled material. If any burning material or matter at a temperature above the auto-ignition temperature of the fine dust passes through this cloud, a deflagration is likely to result. (See Figure B.4.5.5.)

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 intro-

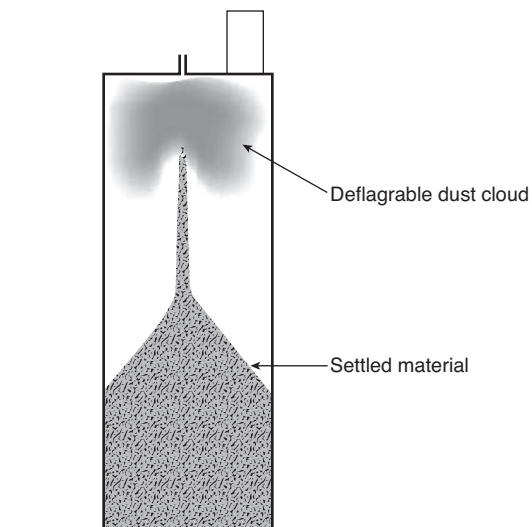


FIGURE B.4.5.5 A Silo Serves as a Particle Size Separator and Becomes an Explosion Hazard. (Courtesy: J.M. Cholin Consultants, Inc.)

duced into the silo, the greater the concentration of dust in that cloud.

B.4.5.5.3 Is there sufficient concentration to propagate a flame front? Eventually, yes. The large particulate displaces air where it accumulates in the silo, producing an upward air current that keeps the fine particulate suspended. The more material that is introduced into the silo, the greater the concentration of dust in that cloud.

B.4.5.5.4 Are there competent ignition sources 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 ignition sources 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.

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 proc-

ess (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 ignition sources 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 ignition sources 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 ignition sources 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 or 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 ignition sources 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/m³; 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 ignition sources 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.