NFPA®

484

Standard for Combustible Metals

2022

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Standard for Combustible Metals

2022 Edition

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NFPA® 484

Standard for

Combustible Metals

2022 Edition

This edition of NFPA 484, *Standard for Combustible Metals*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts, released by the Correlating Committee on Combustible Dusts, and acted on by the NFPA membership during the 2021 NFPA Technical Meeting held June 14–July 2. It was issued by the Standards Council on August 26, 2021, with an effective date of September 15, 2021, and supersedes all previous editions.

This document has been amended by one or more Tentative Interim Amendments (TIAs) and/or Errata. See "Codes & Standards" at www.nfpa.org for more information.

This edition of NFPA 484 was approved as an American National Standard on September 15, 2021.

Origin and Development of NFPA 484

The 2002 edition of NFPA 484, then titled *Standard for Combustible Metals, Metal Powders, and Metal Dusts*, was a comprehensive combustible metal fire safety document. It was created by taking the requirements of the metals standards NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*; NFPA 481, *Standard for the Production, Processing, Handling, and Storage of Titanium*; NFPA 482, *Standard for the Production, Processing, Handling, and Storage of Zirconium*; NFPA 485, *Standard for the Storage, Handling, Processing, and Use of Lithium Metal*; NFPA 65, *Standard for the Processing and Finishing of Aluminum*; and NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*, and making them into individual chapters in NFPA 484. Chapter 10 was written to address combustible metals not covered by one of the metal-specific chapters. Additionally, a metal-specific chapter was written for tantalum because of its increased use. Thus, the original edition of NFPA 484 provided safety requirements for all combustible metals, including for processing, storage, handling, dust collection, housekeeping, and fire protection.

The 2006 edition of NFPA 484, *Standard for Combustible Metals*, contained several major changes, including a new title. A new chapter, Chapter 4, included test requirements for classifying a material as a combustible metal. Other new chapters were Chapter 5, which addressed alkali metals; Chapter 8, which addressed niobium; and Chapter 13, which consolidated the fire protection requirements from Chapters 5 through 12.

The 2009 edition of NFPA 484 contained the following changes:

(1) Addition of new Chapter 14, Combustible Metal Recycling Facilities
(2) Addition of thresholds in Table 1.1.9 for applicability of the document; before this change, the standard applied to any amount of a combustible metal
(3) Updates to the recommended suppression materials in Table A.13.3.3

The 2012 edition of NFPA 484 contained the following changes:

(1) A unified format was applied for chapter-to-chapter consistency for the individual combustible metals in the document.
(2) New definitions were added for *dust explosion* and *dust flash-fire hazard area* and a number of particular terms, including *metal dust, fines, superfines, ultrafines, flakes, paste,* and *ribbon*. A definition for *screening test* was also added. The committee clarified when the standard would apply rather than when the standard would not apply. New information was included in Chapter 16 to clarify the requirements for testing and classifying potentially combustible metals.

(3) Management of change requirements were added to chapters where they had not been previously identified.
(4) New information was added about wet dust collection systems and housekeeping, both of which are important issues for the prevention of fires and explosions. Personal protective equipment (PPE) requirements were also identified.
(5) Chapter 15, Fire Prevention, Fire Protection, and Emergency Response, remained retroactive for all of the specific metal chapters and for the general metal chapter.
(6) Chapter 16, Combustible Metal Recycling Facilities, was retroactive. In addition, information was added to address emergency response requirements.
(7) Hazard analysis requirements were made applicable to all metal chapters.
(8) A new chapter on performance-based design was added.

The 2015 edition of NFPA 484 revised a provision in Chapter 1 that established a framework for the protection of mixtures of metals and other combustible dusts and included revised definitions in Chapter 3. Chapter 4 was changed to include revised procedures for material characterization and determining combustibility and explosibility of metal dusts. As part of those requirements, test data or historical data were permitted to be used. Chapter 5 was changed to include requirements for management system elements, such as management of change, hazard analysis, and personal protective equipment. As part of an effort to consolidate the fundamental requirements within dedicated chapters, ignition control sources, such as hot work and static electricity, were moved from Chapter 6 to Chapter 8 and retitled Control of Ignition Sources. Chapter 6 was revised to include new requirements for emergency response and preparedness. In Chapter 7, the committee established a threshold for fugitive dust accumulations, which was used to trigger specific requirements related to dust hazard control. Chapter 9 was modified to include requirements for pneumatic conveying systems. The committee also modified Chapters 11 through 18 by moving requirements common to all the metal types (such as PPE, management of change, dust collection, ignition sources, and hazard analysis) to the fundamental chapters (Chapters 4 through 9). The committee also added acceptance criteria to Chapter 19 for metal recycling.

The 2019 edition of NFPA 484 was a complete reorganization of the document. Many of the changes were made to align the document with NFPA 652, *Standard on the Fundamentals of Combustible Dust*. A new Chapter 7 was added on Dust Hazard Analysis.

Chapter 4, General, was revised to include material on objectives and compliance options to align with NFPA 652. It was also modified to include requirements on Management of Change and Personnel Protective Equipment.

New chapters were added to the document on Nanometals (Chapter 12) and Additive Manufacturing (Chapter 13) to reflect emerging technologies and issues in the metals industry. Chapter 11, Powder and Dust Collection and Centralized Vacuum Systems, was completely rewritten to provide clarity for users. Chapter 15, Legacy Metals, consolidated the common requirements for aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium into a single location. Note that the material specific to these metals remains in the metal-specific chapters.

In addition to the above changes, definitions in Chapter 3 were reviewed and updated to correlate with those in NFPA 652, the fundamentals document. Where requirements in the code were retroactive, statements were included to clearly indicate that to the user. Material was added to the scope in Chapter 1 to clarify the application of the standard to mixtures of metals and other combustible nonmetal dusts. Changes in Chapter 8 clarified and strengthened the requirements regarding static electricity. Changes were also made to the requirements for electrical area classification from *NFPA 70®*, *National Electrical Code®*, to clarify that the committee did not agree with the definition of combustible dust found in *NFPA 70*. The committee also clarified that the zone classification system must not be used for metal dusts.

For the 2022 edition, the standard has been reorganized so that the first nine chapters correlate with the topics covered in NFPA 652, as well as to organize the remaining chapters so that the requirements in the first nine chapters do not conflict with other areas of the standard. Language has been added to the annex to address hazards that might exist in quantities under the standard's applicability thresholds.

In addition, a requirement has been added for the K_{st} value to be doubled for certain metals unless their explosibility characteristics are determined in a 1 m^3 or larger test vessel, and annex material has been added to explain this requirement. The requirements for fire detection for dry-type air-material separators have also been revised to allow for methods other than surface-mounted devices and to require that all filter locations (if present) be monitored.

The Legacy Metals chapter has been reorganized to consolidate the requirements that apply to all legacy metals, and the chapter on Additive Manufacturing has been revised to address the growing utilization of metal powders in additive manufacturing, addressing dust hazard analysis, the location of emergency shutdown controls, harvesting printed objects, powder storage, and operator training.

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

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Committee Scope: This Committee shall have primary responsibility for documents on safeguards against fire and explosion in the manufacturing, processing, handling, and storage of combustible metals, powders, and dusts.

Contents

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Standard for

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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.

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

Chapter 1 Administration

1.1* Scope. This standard 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.

1.1.1* The procedures in Chapter 5 shall be used to determine whether a metal is in a noncombustible form.

1.1.2 Combustible Metals.

1.1.2.1 This standard provides requirements for operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible metal in any form.

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

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.

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.

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 Chapter 18.

1.1.5 Materials submitted for recycling or waste disposal shall be subject to the requirements of Chapter 19.

1.1.6* This standard provides requirements for mixtures that contain metals exhibiting combustion characteristics of metals covered by this standard. *(See 5.2.4 for additional information on testing and characterization.)*

1.1.6.1 Metal only mixtures shall be subject to the requirements of this standard.

Δ **1.1.6.2*** Metal-containing mixtures that also contain combustible nonmetal dusts shall be permitted to be excluded from this standard and protected according to NFPA 652 and NFPA 654 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 ABC 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.

1.1.7* This standard shall not apply to the transportation of metals in any form on public highways and waterways or by air or rail.

1.1.8 This standard shall not apply to the primary production of aluminum, magnesium, and lithium.

1.1.9 This standard shall apply to laboratories that handle or use more than 0.23 kg (½ lb) of alkali metals or 0.907 kg (2 lb) aggregate of other combustible metals, excluding alkali metals.

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 1.1.11.

1.1.10 All alkali metals and metals that are in a form that is water reactive shall be subject to this standard.

1.1.11* If the quantity of a combustible metal listed in Table 1.1.11 is exceeded in an occupancy, the requirements of this document shall apply.

1.2 Purpose. The objective of this standard shall be to minimize the occurrence of, and resulting damage from, fire or explosion in areas where combustible metals or metal dusts are produced, processed, finished, handled, stored, and used.

Table 1.1.11 Applicability Thresholds by Occupancy

Occupancy Class (as defined in *NFPA 5000*)	Threshold Quantity (kg)	Threshold Quantity (lb)
Assembly	0.454	1
Educational	0.23 kg of alkali metals or 0.907 aggregate of other combustible metals, excluding alkali metals	½ lb of alkali metals or 2 aggregate of other combustible metals, excluding alkali metals
Day care	Not permitted	Not permitted
Health care	0.907	2
Ambulatory health care	0.907	2
Detention and correctional	Not permitted	Not permitted
Residential	0.907	2
Residential board and care	Not permitted	Not permitted
Mercantile	0.907	2
Business	4.535	10 for storage; 0 for use and handling
Industrial	2.268	5
Storage	22.675	50

1.3 Application.

1.3.1 The provisions of this document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion.

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N **1.3.2** This standard shall be used to supplement the requirements established by NFPA 652.

1.4 Conflicts.

1.4.1 Where a conflict exists between a requirement of NFPA 652 and a requirement of this standard, the requirement of this standard shall apply.

1.4.2 Where a requirement specified in this standard specifically prohibits a requirement specified in NFPA 652, the prohibition in this standard shall apply.

N **1.4.3** Where this standard neither prohibits nor provides a requirement, the requirement in NFPA 652 shall apply.

N **1.4.4** Where a conflict between a general requirement of this standard and a specific requirement of this standard exists, the specific requirement shall apply.

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

1.5.1 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.

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

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

1.5.4 The retroactive requirements of this standard shall be permitted to be modified if their application clearly would be impractical in the judgment of the authority having jurisdiction, and only where it is clearly evident that a reasonable degree of safety is provided.

1.6 Equivalency. Nothing in this standard shall be 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, provided technical documentation is made available to the authority having jurisdiction to demonstrate equivalency, and the system, method, or device is approved for the intended purpose.

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.

N **1.7.4** 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.

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,* 2021 edition.
NFPA 2, *Hydrogen Technologies Code,* 2020 edition.
NFPA 10, *Standard for Portable Fire Extinguishers,* 2022 edition.
NFPA 11, *Standard for Low-, Medium-, and High-Expansion Foam,* 2021 edition.
NFPA 12, *Standard on Carbon Dioxide Extinguishing Systems,* 2021 edition.
NFPA 12A, *Standard on Halon 1301 Fire Extinguishing Systems,* 2021 edition.
NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2022 edition.
NFPA 14, *Standard for the Installation of Standpipe and Hose Systems,* 2019 edition.
NFPA 15, *Standard for Water Spray Fixed Systems for Fire Protection,* 2022 edition.
NFPA 16, *Standard for the Installation of Foam-Water Sprinkler and Foam-Water Spray Systems,* 2019 edition.
NFPA 17, *Standard for Dry Chemical Extinguishing Systems,* 2021 edition.

NFPA 20, *Standard for the Installation of Stationary Pumps for Fire Protection,* 2022 edition.

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

NFPA 24, *Standard for the Installation of Private Fire Service Mains and Their Appurtenances,* 2022 edition.

NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems,* 2020 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2021 edition.

NFPA 31, *Standard for the Installation of Oil-Burning Equipment,* 2020 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2021 edition.

NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids,* 2021 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals,* 2019 edition.

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

NFPA 54, *National Fuel Gas Code,* 2021 edition.

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

NFPA 69, *Standard on Explosion Prevention Systems,* 2019 edition.

NFPA 70®, *National Electrical Code*®, 2020 edition.

NFPA 72®, *National Fire Alarm and Signaling Code*®, 2022 edition.

NFPA 77, *Recommended Practice on Static Electricity,* 2019 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2022 edition.

NFPA 85, *Boiler and Combustion Systems Hazards Code,* 2019 edition.

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

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

NFPA *101*®, *Life Safety Code*®, 2021 edition.

NFPA 220, *Standard on Types of Building Construction,* 2021 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2021 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2021 edition.

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

NFPA 600, *Standard on Facility Fire Brigades,* 2020 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust,* 2022 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2020 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,* 2019 edition.

NFPA 1081, *Standard for Facility Fire Brigade Member Professional Qualifications,* 2018 edition.

NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems,* 2021 edition.

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

NFPA 2113, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire,* 2020 edition.

NFPA 5000®, *Building Construction and Safety Code*®, 2021 edition.

2.3 Other Publications.

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

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

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

ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*, 2020.

ASTM E136, *Standard Test Method for Assessing Combustibility of Materials Using a Vertical Tube Furnace at 750°C*, 2019a.

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

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

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

ASTM E2931, *Standard Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*, 2013, 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.

ISO/ASTM 52900, *Standard Terminology for Additive Manufacturing — General Principles — Terminology*, 2015.

N **2.3.3 IEC Publications.** International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211 Geneva 20, Switzerland.

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

2.3.4 ISA Publications. International Society of Automation, 67 T. W. Alexander Drive, PO Box 12277, Research Triangle Park, NC 27709.

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

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

UN Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria, 5th edition, 2009.

2.3.6 Other Publications.

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

2.4 References for Extracts in Mandatory Sections.

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

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

NFPA 69, *Standard on Explosion Prevention Systems,* 2019 edition.

NFPA 70®, National Electrical Code®, 2020 edition.

NFPA 77, *Recommended Practice on Static Electricity,* 2019 edition.

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

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2021 edition.

NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas,* 2021 edition.

NFPA 652, *Standard on the Fundamentals of Combustible Dust,* 2019 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2020 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2021 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.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

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

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

3.2.5 Shall. Indicates a mandatory requirement.

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

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

3.3 General Definitions.

N **3.3.1 Abort Gate/Damper.** A device for the quick diversion of material or air to the exterior of a building or other safe location in the event of a fire. [**652,** 2019]

N **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,** 2015]

Δ **3.3.3* Air-Material Separator (AMS).** A device designed to separate the conveying air from the material being conveyed. [**652,** 2019]

3.3.3.1 ***Enclosureless AMS.*** An air-material separator designed to separate the conveying air from the material being conveyed where the filter media are not enclosed or in a container. [**652,** 2019]

3.3.4* Air-Moving Device (AMD). A power-driven fan, blower, or other device that establishes an airflow by moving a given volume of air or gas per unit time. [**652,** 2019]

3.3.5 Alkali Metals. See 3.3.52.1.

3.3.6 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.

3.3.7 Aluminum Powder. See 3.3.63.3.

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. [**652,** 2019]

3.3.9 Castings. An object or finished shape obtained by solidification of a substance in a mold.

3.3.9.1* ***Heavy Casting.*** Castings greater than 11.3 kg (25 lb) with walls of large cross-sectional dimensions [at least 6.4 mm (¼ in.)].

3.3.10* 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). [**652,** 2019]

3.3.11* Chips. Particles produced from a cutting or machining operation that are not oxidized and that are not diluted by noncombustible materials.

3.3.12* 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. [**652,** 2019]

3.3.13* 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,** 2021]

3.3.14 Combustible Metal. See 3.3.52.2.

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

3.3.14.2 ***Combustible Metal Particulate.*** See 3.3.14.1, Combustible Metal Dust.

3.3.14.3* ***Metal Dust.*** Particulate metal resulting from a solid state secondary processing operation.

3.3.15* 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. [**652,** 2019]

3.3.16 Compartment. A subdivision of an enclosure. [**652,** 2019]

N **3.3.17* Conductive.** Possessing the ability to allow the flow of an electric charge. [**652**, 2019]

N **3.3.17.1** ***Conductive Dusts.*** Dusts with a volume resistivity of less than 10^6 ohm-m. [**652,** 2019]

N **3.3.18 Conductor.** A material or object that allows an electric charge to flow easily through it. [**77,** 2019]

3.3.19* Critical Process. A process that has the potential to cause harm to personnel, equipment, structures, or product in the event of an uncontrolled failure.

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

3.3.21 Deflagration Hazard Area.

3.3.21.1 ***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.

3.3.21.2 ***Dust Flash-Fire Hazard Area.*** An area where combustible dust accumulation on exposed or concealed surfaces, outside of equipment or containers, can result in personnel injury from thermal dose during a dust deflagration, as well as any areas where dust clouds of a hazardous concentration exist during normal operation. A propagating deflagration yield a flash-fire through the hazard area.

3.3.22 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. [**654,** 2020]

N **3.3.23* Dissipative.** A material or a construction that will reduce static charge to acceptable levels. [**77**, 2019]

3.3.24 Dryer. A piece of processing equipment using temperature or pressure change to reduce the moisture or volatile content of the material being handled. [**654,** 2020]

3.3.25 Duct. Pipes, tubes, or other enclosures used for the purpose of pneumatically conveying materials. [**91,** 2020]

3.3.26 Dust. See 3.3.14.1, Combustible Metal Dust.

3.3.26.1* ***Dust Collection System.*** A combination of equipment designed to capture, contain, and pneumatically convey fugitive dust to an air-material separator (AMS) in order to remove the dust from the process equipment or surrounding area. [**652,** 2019]

3.3.26.1.1 ***Dry-Type AMS.*** A device that does not use liquid to separate the material being conveyed from the conveying medium, such as cyclones or media collectors.

3.3.26.1.2 ***Wet-Type AMS.*** A device that uses liquid to separate the material being conveyed from the conveying medium.

3.3.26.2 ***Dust Deflagration Hazard.*** A condition that presents the potential for harm or damage to people, property, or the environment due to the combustion of a sufficient quantity of combustible dust suspended in air or another oxidizing medium. [**652,** 2019]

3.3.26.3 ***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. [**652,** 2019]

3.3.26.4* ***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. [**652,** 2019]

3.3.27 Eutectic Reaction. (Reserved)

3.3.28* Explosible. Capable of propagating a deflagration when dispersed in air or the process-specific oxidizing media. [**652,** 2019].

3.3.29 Explosion. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. [**69,** 2019]

3.3.30 Fines. The portion of a powder composed of particles that are smaller than 45 microns (U.S. Standard Sieve No. 325); also known as the subsieve size fraction.

3.3.30.1 ***Superfines.*** Particles smaller than 10 microns (μm).

3.3.30.2 ***Ultrafines.*** Particles with size generally less than 0.1 micron (μm).

3.3.31 Fire Hazard. Any situation, process, material, or condition that, on the basis of applicable data, can cause a fire or provide a ready fuel supply to augment the spread or intensity of a fire and poses a threat to life or property. [**652,** 2019]

3.3.32* Fire-Resistive. Meeting the requirements for Type I or Type II construction.

3.3.33 Flake. A flat or scale-like particulate material that is relatively thin with a large aspect ratio.

3.3.34* Flash Fire. A deflagration that spreads through a combustible dust, gas, or vapor cloud without the production of damaging pressure.

3.3.35 Fuel Object. A combustible object or mass of particulate that can serve as a source of fuel for a fire or deflagration; sometimes referred to as a *fuel package*. [**652,** 2019]

3.3.36 Fugitive Dusts. Dust that escapes from equipment and containers. [**652,** 2019]

3.3.37 Fugitive Material. See 3.3.49.1.

3.3.38 Grounding. The process of bonding one or more conductive objects to the ground so that all objects are at zero electrical potential; also referred to as *earthing*. [**652,** 2019]

3.3.39 Handling. 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.

3.3.40 Hazard Analysis. A documented assessment performed by personnel knowledgeable of the specific hazards of the material and that is acceptable to the AHJ.

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

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

N **3.3.43* 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:**100]

3.3.44* Ignitible 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 ignitible layer fire hazard. [**499,** 2021]

3.3.45* 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.

3.3.46* Industry- or Commodity-Specific Standard. An NFPA code or standard whose intent as documented within its purpose or scope is to address fire and explosion hazards of a combustible particulate solid. [**652,** 2019]

N **3.3.47 Intermediate Bulk Containers.** [**652,** 2019]

N **3.3.47.1*** ***Flexible Intermediate Bulk Container (FIBC).*** Large bags typically made from nonconductive woven fabric that are used for storage and handling of bulk solids. [**652,** 2019]

N **3.3.47.1.1** ***Type A FIBC.*** An FIBC made from nonconductive fabric with no special design features for control of electrostatic discharge hazards. [**652,** 2019]

N **3.3.47.1.2** ***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. [**652,** 2019]

N **3.3.47.1.3** ***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. [**652,** 2019]

N **3.3.47.1.4** ***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. [**652,** 2019]

N **3.3.47.2*** ***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. [**652,** 2019]

N **3.3.47.2.1** ***Insulating RIBC.*** An RIBC constructed entirely of solid plastic or solid plastic and foam composite that cannot be electrically grounded. [**652,** 2019]

3.3.48 Limiting Oxidant Concentration (LOC). The concentration of oxidant in a fuel-oxidant-diluent mixture below which a deflagration cannot occur under specified conditions. [**69,** 2019]

3.3.49 Material.

3.3.49.1 ***Fugitive Material.*** Any particle, regardless of size, that is lost from manufacturing or other processes.

3.3.49.2* ***Pyrophoric Material.*** A material that ignites upon exposure to air at or below 54.4°C (130°F).

3.3.49.3* ***Spark-Resistant Material.*** A material that is not prone to generate impact sparks under conditions of use.

3.3.50 Media Collector. An air-material separator (AMS) that uses filter bags or cartridges for air/gas flow and dust separation.

3.3.51* Mesh Size. The dimensions of a mesh that are specified in ASTM E11, *Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves*.

3.3.52* 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.

3.3.52.1 ***Alkali Metals.*** Cesium, francium, lithium, potassium, rubidium, sodium, and alloys of these metals, such as NaK.

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

3.3.52.3* ***Legacy Metals.*** The metals aluminum, magnesium, niobium, tantalum, titanium, zirconium, and hafnium.

3.3.52.4 ***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.

3.3.52.5* ***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.

Δ **3.3.53* 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. [**652,** 2019]

Δ **3.3.54* 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. [**652,** 2019]

3.3.55 Mixtures. (Reserved)

3.3.56* 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 Section 14.2.2.)*

3.3.57* Noncombustible. In the form used and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat.

3.3.58 Passivation. A controlled process by which a barrier coating is placed on the surface of the metal to inhibit reaction.

3.3.58.1 ***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.

3.3.59 Paste. A mixture consisting of a liquid and suspended particles or flakes.

3.3.59.1 ***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.

3.3.60* 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. [**652,** 2019]

3.3.61 Portable AMS (Dust Collector). A portable machine designed to collect airborne dust produced from a dust-generating operation.

3.3.62 Portable Vacuum Cleaner. A movable assembly consisting basically of a vacuum source [air-moving device (AMD)], an air-material separator (AMS) using either liquid or filter media within an enclosure, and a vacuum hose, used to remove dusts and particles from surfaces. [**652,** 2019]

3.3.63 Powder. Particles of matter intentionally manufactured to a specific size and shape. Typically, powders are less than 1 millimeter and can be elemental or alloy in composition and regular, irregular, spherical, sponge, granular, dendritic, or nodular in shape.

3.3.63.1* ***Aluminum Flake Powder.*** See 3.3.63.3, Aluminum Powder.

3.3.63.2 ***Aluminum Granular Powder.*** See 3.3.63.3, Aluminum Powder.

3.3.63.3* ***Aluminum Powder.*** Aluminum powder is divided into three broad classifications: atomized, flake, and granules.

3.3.63.4* ***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.

3.3.63.5 ***Tantalum Powder.*** Nodular or flake-like tantalum particles that will pass through a 20 mesh screen [850 μm (microns)] as discrete particles or as agglomerates of discrete particles.

3.3.63.5.1 ***Unrefined Tantalum Powder.*** Any tantalum powder that contains impurities, such that further refinement is required to produce a tantalum product suitable for commercial use.

3.3.64* Powder Production Plant. Facilities or buildings in which the primary product is powder.

3.3.65 Pyrophoric Material. See 3.3.49.2.

3.3.66 Qualified Person. A person who, by possession of a recognized degree, certificate, professional standing, or skill, and who, by knowledge, training, and experience, has demonstrated the ability to deal with problems related to the subject matter, the work, or the project. [**1451,** 2018]

3.3.67* 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.

3.3.68 Replacement-in-Kind. A replacement that satisfies the design specifications of the replaced item. [**652,** 2019]

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

3.3.69.1* ***Magnesium Ribbon.*** Magnesium metal that is less than 3.2 mm (⅛ in.) in two dimensions or less than 1.3 mm (1⁄20 in.) in single dimension, also considered a powder for the purpose of this standard.

3.3.70* Risk Assessment. An assessment of the likelihood, vulnerability, and magnitude of the incidents that could result from exposure to hazards. [**1250,** 2020]

3.3.71 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.

Δ **3.3.72 Segregation.** A hazard management strategy in which a physical barrier is established between the hazard area and an area to be protected. [**652,** 2019]

Δ **3.3.73 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. [**652,** 2019]

Δ **3.3.74* Spark.** A localized source of thermal or electrical energy capable of igniting combustible material. [**652,** 2019]

N **3.3.74.1*** ***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. [**652,** 2019]

N **3.3.74.2*** ***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. [**652,** 2019]

3.3.75 Spark-Resistant Material. See 3.3.49.3.

3.3.76* Sponge. A porous metal product obtained by processing metal ore prior to being melted.

3.3.77 Spontaneous Heating. Process whereby a material increases in temperature without drawing heat from its surroundings. [**921,** 2021]

N **3.3.78 Static Dissipative.** See 3.3.23, Dissipative.

3.3.79 Swarf. Particles produced from a cutting, machining, or grinding operation that causes partial oxidation of the parent material or dilution by other inert materials.

3.3.80 Tantalum Powder. See 3.3.63.5.

3.3.81 Tantalum Ultrafines. (Reserved)

3.3.82* Thermite Reaction. The exothermic reaction between a metal and any metal oxide lower in the electromotive series.

3.3.83 Threshold Housekeeping Dust Accumulation. The maximum quantity of dust permitted to be present before cleanup is required. [**652,** 2019]

3.3.84 Titanium Fines. (Reserved)

3.3.85 Wall.

3.3.85.1 ***Fire Barrier Wall.*** A wall, other than a fire wall, having a fire resistance rating. [**221,** 2021]

3.3.85.2 ***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,** 2021]

3.3.86 Zirconium Fines. (Reserved)

Chapter 4 General Requirements

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

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

[**652:**4.1]

4.2 Objectives. The objectives stated in this section shall be interpreted as intended outcomes of this standard and not as prescriptive requirements. [**652:**4.2]

Δ **4.2.1 Life Safety.**

N **4.2.1.1*** The facility, processes, and equipment shall be designed, constructed, equipped, and maintained and management systems shall be implemented to reasonably protect occupants not in the immediate proximity of the ignition from the effects of fire for the time needed to evacuate, relocate, or take refuge. [**652:**4.2.1.1]

N **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. [**652:**4.2.1.2]

N **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. [**652:**4.2.1.3]

N **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. [**652:**4.2.1.4]

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Δ **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. [**652:**4.2.2]

Δ **4.2.3* Mitigation of Fire Spread and Explosions.** The facility and processes shall be designed to prevent or mitigate fires, explosions, or consequential releases of hazardous materials that can cause failure of adjacent buildings or building compartments or other enclosures, emergency life safety systems, adjacent properties, adjacent storage, or the facility's structural elements. [**652:**4.2.3]

4.2.4* Compliance Options. The objectives in Section 4.2 shall be achieved by either of the following means:

(1) A prescriptive approach in accordance with Chapter 5 and Chapters 7 through 19, as applicable
(2) A performance-based approach in accordance with Chapter 6

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4.2.5 Where a dust fire, deflagration, or explosion hazard exists within a process system, the hazards shall be managed in accordance with this standard. [**652:**4.2.5]

4.2.6 Where a dust fire, deflagration, or explosion hazard exists within a building or building compartment, the effects of the fire, deflagration, or explosion shall be managed in accordance with this standard. [**652:**4.2.6]

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Chapter 5 Hazard Identification — Determination of the Combustibility or Explosibility of a Metal, Metal Powder, or Metal Dust

N **5.1 Responsibility.** The owner/operator of a facility with potentially combustible dusts shall be responsible for determining whether the materials are combustible or explosible, and, if so, for characterizing their properties as required to support the DHA. [**652:**5.1]

N **5.1.1** Where dusts are determined to be combustible or explosible, the hazards associated with the dusts shall be assessed in accordance with Chapter 7. [**652:**5.1.1]

N **5.1.2** Where dusts are determined to be combustible or explosible, controls to address the hazards associated with the dusts shall be identified and implemented in accordance with 4.2.4. [**652:**5.1.2]

5.2* Overview. The screening test in Section 5.4 and in Section 5.5 shall be conducted to determine if a metal is in combustible or explosible form.

5.2.1 If either of the tests produces a positive result, the material shall be considered a combustible metal.

5.2.2 Test results shall be documented, the AHJ shall be notified, and the test results shall be provided when requested.

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 standard.

5.2.4 Application of This Document.

Δ **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 document. *(See 1.1.6 for additional information.)*

5.2.4.2 Wherever combustibility can be shown to exist in these materials, the full scope and requirements of this document shall apply.

5.2.4.3 Wherever the documentation necessary for compliance with 5.2.2 and 5.2.3 is lacking, the requirements of this document shall apply.

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.

5.2.5.1 Representative samples shall be collected from the process and preserved in suitable inert gas or vacuum packaging until tested.

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.

5.3* Basic Material Characterization.

5.3.1* Representative samples and components of metal-containing mixtures shall be collected and identified.

5.3.2* 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.

5.4 Determination of Combustibility.

5.4.1* 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*.

5.4.1.1 Representative samples shall be maintained in suitable inert gas or vacuum packaging until tested.

5.4.2 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

5.4.3 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.

5.4.4* 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.

5.4.5* For materials other than dusts, powders, pastes, or other finely divided material, the flame from a 1000°C (1832°F) torch shall be applied for 10 minutes.

5.4.5.1* If the material does not sustain combustion, it shall be considered to be a metal in a noncombustible form.

5.4.5.2 Safety measures shall be taken based on the assumption that the test will result in combustion.

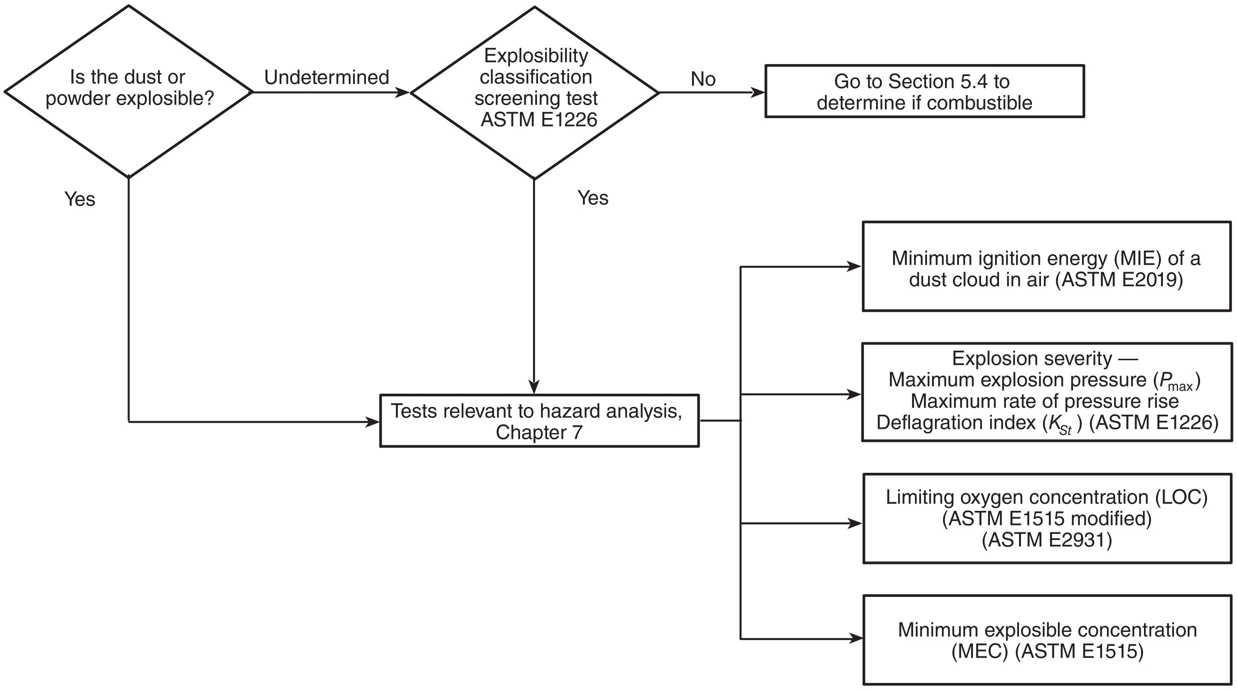
5.5 Determination of Explosibility.

5.5.1* The explosibility of metals, metal powders, metal dusts, and alloys of these materials shall be determined by using the flow chart in Figure 5.5.1.

N **5.5.1.1*** 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 m^3 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.

Δ **5.5.1.2*** If the material is determined to be explosible, some or all of the standard test methods mentioned in Figure 5.5.1 shall be performed as needed for the hazard analysis as described in Chapter 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.

5.5.1.3 Additional tests chosen shall be those relevant to hazard analysis of the intended explosion protection techniques and flash-fire hazards anticipated for the process.



Δ **FIGURE 5.5.1 Determination of Explosibility.**

5.5.2* 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.

5.5.3* 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.

5.5.3.1 Representative samples shall be maintained in suitable inert gas or vacuum packaging until tested.

5.5.4* The explosibility classification screening tests shall be conducted in accordance with ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds.*

5.6 Use of Test Data for Hazard Analysis.

5.6.1* The hazard analysis shall be based on data from tests of collected samples or historical data.

5.6.2* 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.

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

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N **5.8* Organometallic Materials. (Reserved)**

Chapter 6 Performance-Based Design Option

6.1 General Requirements.

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

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

6.1.3* Performance-based designs shall be documented with all calculations, references, assumptions, and sources from which material characteristics and other data have been obtained or on which the designer has relied for some material aspect of the design in accordance with Chapter 5 of NFPA *101.*

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

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

6.1.4* Performance-based designs and documentation shall be updated and subject to re-approval if any of the assumptions on which the original design was based are changed.

6.1.5 Sources of Data.

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

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

6.2 Design Objectives.

6.2.1 Life Safety.

6.2.1.1 The facility, combustible particulate processes, and human element programs shall be designed, constructed, equipped, and maintained to protect personnel not in the immediate proximity of the ignition from the effects of fire, deflagration, explosion, or the consequential release of hazardous materials for the time needed to evacuate, relocate, or take refuge.

6.2.1.2 The structure shall be located, designed, constructed, and maintained to minimize the propagation of fire, explosion, or the consequential release of hazardous materials to adjacent properties and to avoid injury to the public.

6.2.2 Structural Integrity. The facility shall be designed, constructed, and equipped to maintain its structural integrity in spite of the effects of fire, explosion, or the consequential release of hazardous materials for the time necessary to evacuate, relocate, or defend in place occupants not in the immediate proximity of the ignition.

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

6.2.4 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.

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

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

6.3 Performance Criteria. A system and facility design shall be deemed to meet the objectives specified in Section 6.2 if its performance meets the criteria in 6.3.1 through 6.3.5.

6.3.1 Life Safety.

6.3.1.1 The life safety objectives of 6.2.1 with respect to a fire hazard shall be achieved if either of the following criteria is met:

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

6.3.1.2 The life safety objectives of 6.2.1 with respect to an explosion hazard shall be achieved if either of the following criteria is met:

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

6.3.1.3 The life safety objectives of 6.2.1 with respect to the consequential release of hazardous materials that don't result in a fire or explosion shall be achieved if the following criteria are met:

(1) The physical and health hazards identified are mitigated.
(2) Releases of all hazardous materials offsite are minimized.

6.3.2 Structural Integrity. The structural integrity objective of 6.2.2 with respect to fire and explosion shall be achieved when no critical structural element of the building is damaged to the extent that it can no longer support its design load under all fire and explosion scenarios.

6.3.3 Mission Continuity. The mission continuity objectives of 6.2.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

6.3.4 Mitigation of Fire Spread, Explosions, or the Consequential Release of Hazardous Materials. When limitation of fire spread is to be achieved, all of the following criteria shall be demonstrated:

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

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

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

6.4* Design Scenarios.

6.4.1 Fire Scenarios.

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

6.4.2 Explosion Scenarios.

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

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

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

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

6.4.2.5 Other Explosions Such as Hydrogen, Steam, Chemical, or Hazardous Materials Reactions. (Reserved)

6.5 Evaluation of Proposed Design.

6.5.1* General. A proposed design's performance shall be assessed relative to each performance objective in Section 6.2 and each applicable scenario in Section 6.4, with the assessment conducted through the use of appropriate calculation methods acceptable to the authority having jurisdiction.

6.5.2 The design professional shall establish numerical performance criteria for each of the objectives in Section 6.2.

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

6.6 Retained Prescriptive Requirements. 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.

Chapter 7 Hazard Analysis

7.1* General Requirements.

7.1.1* Retroactivity. The requirements of Chapter 7 shall apply retroactively.

7.1.2 Solid metal in a combustible form shall meet the requirements of Section 5.3.

7.1.3 Combustible metal dusts shall meet the requirements of Section 7.2.

7.1.4 Molten combustible metals shall meet the requirements of Section 7.3.

7.1.5 The design of the fire and explosion safety provisions shall be based on a hazard analysis of the facility, the process, and the associated fire and explosion hazards.

7.2 Dust Hazard Analysis (DHA).

7.2.1 Responsibility. The owner/operator of a facility where materials that have been 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. [**652:**7.1.1]

7.2.1.1 For existing processes and facility compartments that are undergoing modification, the owner/operator shall complete a DHA.

7.2.1.2 New or altered operations, equipment, or facilities shall be reviewed for potential hazards prior to operation.

7.2.1.3* The design of the fire and explosion safety provisions shall be based on a hazard analysis of the facility, the process, and the associated fire and explosion hazards.

7.2.1.4 The DHA shall be reviewed and updated at least every five years.

7.2.2 Criteria.

7.2.2.1* Overview. The DHA shall evaluate the fire, deflagration, reactivity, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.2. [**652:**7.2.1]

7.2.2.2* Qualifications. The DHA shall be performed or led by a qualified person. [**652:**7.2.2]

7.2.2.2.1 The DHA shall be signed off, prior to operation, by a cognizant authority at the facility.

7.2.2.3 Documentation. The results of the DHA review shall be documented, including any necessary action items requiring change to the process materials, physical process, process operations, or facilities associated with the process. [**652:**7.2.3]

7.2.2.3.1 The results of the hazard analysis shall be maintained for the life of the process.

7.2.3 Methodology.

7.2.3.1 General. The DHA shall include the following:

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

[**652:**7.3.1]

7.2.3.1.1 Recommendations from the DHA shall be tracked to completion.

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

7.2.3.3 Process Systems.

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

(1) Potential intended and unintended combustible metal dust transport between parts of the process system
(2) Potential fugitive combustible metal dust emissions into a building or building compartments, including powder and fugitive material as defined by this document
(3) Potential deflagration propagation between parts of the process system
(4) Reactivity of the combustible metal

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

(1) Oxidizing atmosphere
(2) Credible ignition source

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

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

7.2.3.4 Building or Building Compartments.

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

7.2.3.4.1.1 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. [**652:**7.3.4.1.1]

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

7.2.3.4.1.3 The evaluation shall address potential deflagration propagation between buildings or building compartments. [**652:**7.3.4.1.3]

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

(1) Oxidizing atmosphere
(2) Credible ignition source

7.2.3.4.2.1 The evaluation of dust deflagration hazard in a building or building compartment shall include a comparison of actual or intended dust accumulation to the threshold housekeeping dust accumulation that would present a potential for flash-fire exposure to personnel or compartment failure due to explosive overpressure. [**652:**7.3.4.2.1]

7.2.3.4.2.2 Threshold housekeeping dust accumulation levels and nonroutine dust accumulation levels (e.g., from a process upset) shall be in accordance with this standard.

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

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

[**652:**7.3.4.3]

7.3 Molten Metal Hazard Analysis.

7.3.1 Responsibility. The owner/operator of a facility where combustible metals are present in a molten state shall be responsible to ensure a hazard analysis is completed in accordance with the requirements of this section.

7.3.1.1 For existing processes and facility compartments that are undergoing modification, the owner/operator shall complete a hazard analysis.

7.3.1.2 New or altered operations, equipment, or facilities shall be reviewed prior to operation for potential hazards.

7.3.1.3 The hazard analysis shall be reviewed and updated at least every five years.

7.3.2 Criteria.

7.3.2.1 Overview. The hazard analysis shall evaluate the fire, reactivity, and explosion hazards and provide recommendations to manage the hazards in accordance with Section 4.2.

7.3.2.1.1 Reactivity hazards shall include potential molten metal/water interactions.

7.3.2.2* Qualifications. The hazard analysis shall be performed or led by a qualified person.

7.3.2.2.1 Hazard analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

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

7.3.2.3.1 The results of the hazard analysis shall be maintained for the life of the process.

7.3.3 Methodology.

7.3.3.1 General. The hazard 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

7.3.3.1.1 Recommendations from the hazard analysis shall be tracked to completion.

7.3.3.1.2 Hazard analyses shall be signed off, prior to operation, by a cognizant authority at the facility.

7.3.3.2 Material Evaluation.

7.3.3.2.1 The hazard analysis shall be based on data that is representative of the molten metal present.

7.3.3.3 Process Systems.

7.3.3.3.1* 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

7.3.3.3.2 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

7.3.3.3.3* 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

7.3.3.4 Building or Building Compartments.

7.3.3.4.1 Each building or building compartment where combustible metal in a molten form is present shall be evaluated.

7.3.3.4.1.1 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. [**652:**7.3.4.1.1]

7.3.3.4.1.2 The evaluation shall address potential combustible molten metal flow between buildings or building compartments.

7.3.3.4.1.3 The evaluation shall address potential fire or explosion propagation between buildings or building compartments. [**652:**7.3.4.1.3]

7.3.3.4.2 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

N **7.4 Risk Evaluation.** Where a risk evaluation (*see Annex I*) 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

N **7.5 Dust Explosion and Flash-Fire Hazard Areas.**

N **7.5.1** 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 chapter — Chapter 16 through 18 — and Chapter 10.

N **7.5.2** Dust explosion hazard 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 hazard analysis determines otherwise.

N Chapter 8 Management Systems

N **8.1 Retroactivity.** This chapter shall be applied retroactively to new and existing facilities and processes. [**652:**8.1]

N **8.2* General.** The procedures and training in this chapter shall be delivered in a language that the participants can understand. [**652:**8.2]

N **8.3 Operating Procedures and Practices.** Operating procedures and practices shall comply with Section 10.3.

N **8.4 Housekeeping.** Housekeeping shall comply with Chapter 11.

N **8.5* Hot Work.**

N **8.5.1*** In addition to the requirements of NFPA 51B, all hot work activities shall comply with the requirements in 8.5.2 through 8.5.5. [**652:**8.5.1]

N **8.5.2*** The area affected by hot work shall be thoroughly cleaned of combustible dust prior to commencing any hot work. [**652:**8.5.2]

N **8.5.3** Equipment that contains combustible dust and is located within the hot work area shall be shut down, shielded, or both. [**652:**8.5.3]

N **8.5.4** When the hot work poses an ignition risk to the combustible dust within equipment, the equipment shall be shut down and cleaned prior to commencing such hot work. [**652:**8.5.4]

N **8.5.5** Floor and wall openings within the hot work area shall be covered or sealed. [**652:**8.5.5]

N **8.5.6** Use of portable electrical equipment that does not comply with the electrical classification of the area where it is to be used shall be authorized and controlled in accordance with the hot work procedure as outlined in Section 8.5. [**652:**8.5.6]

N **8.6* Personal Protective Equipment (PPE).**

N **8.6.1 PPE Hazard Analysis.**

N **8.6.1.1** 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.

N **8.6.1.2*** The PPE hazard analysis shall determine which operations and activities warrant use of primary PPE for molten metals, primary PPE for dust flash fires, and secondary PPE for general work and maintenance in facilities with combustible metals.

N **8.6.2 Primary PPE for Molten Metals.**

N **8.6.2.1** Primary PPE for molten metals shall include all of the items described in paragraphs 8.6.2.2 to 8.6.2.5.

N **8.6.2.2** Face shields, neck protection, and safety glasses shall be used as part of the primary PPE for molten metal exposures.

N **8.6.2.3*** 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.*

N **8.6.2.4** Gloves or mittens shall be worn and shall be loose fitting, easily removable, and compatible with the hazards of the pertinent molten metals.

N **8.6.2.5** Protective footwear shall be high-top leather safety shoes, at least 150 mm (6 in.) high, and appropriate for the hazards of molten metals used in the areas where personnel are working.

N **8.6.3 Primary PPE for Dust Flash Fires.**

N **8.6.3.1*** Primary PPE for dust flash fires shall include flame-resistant garments in accordance with the workplace hazard assessment required by NFPA 2113.

N **8.6.3.2*** Personnel wearing PPE for dust flash fires shall be informed about the limited protection provided by NFPA 2112–compliant garments against the higher-temperature flames and heat fluxes associated with combustible metal dust flash fires.

N **8.6.3.3** Primary PPE for dust flash fires shall be designed to prevent potential accumulations of combustible metal dust in places such as, but not limited to, pant cuffs, sleeve cuffs, and open pockets, and shall have a smooth outer surface that allows dust to be readily brushed off.

N **8.6.3.4** Primary PPE for dust flash fires shall include shirts, trousers, or coveralls.

N **8.6.3.4.1** Trousers or coveralls shall cover the tops of footwear.

N **8.6.3.5** Primary PPE for dust flash fires shall include safety shoes without exposed metal.

N **8.6.3.6*** Primary PPE for dust flash fires shall include gloves made of heat-resistant fabrics.

N **8.6.3.7*** When worn in areas containing dusts with minimum ignition energies less than 100 mJ, primary PPE for dust flash fires shall be made of static-dissipative materials.

N **8.6.4 Secondary PPE for General Work Areas Near or Containing Combustible Metals.**

N **8.6.4.1** Safety glasses with side shields and hard hats shall be required as part of the secondary PPE.

N **8.6.4.2** Outer garments worn as secondary 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.

N **8.6.4.3** Secondary PPE shall have some measure of flame resistance determined as part of the PPE hazard analysis.

N **8.6.4.4*** When worn in areas containing dusts with minimum ignition energies less than 100 mJ, secondary PPE shall be made of static-dissipative materials.

N **8.6.4.5** Secondary PPE worn in areas containing alkali metals shall have an external clothing layer that is impervious to body moisture.

N **8.6.4.5.1*** Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding fire-fighting personnel assigned to a combustible metal fire equipped to the requirements of NFPA 600 or NFPA 1081.

N **8.7 Inspection, Testing, and Maintenance.** Inspection, testing, and maintenance shall comply with Section 10.4.

N **8.8 Training and Hazard Awareness.** Training and hazard awareness shall comply with Section 10.6.

N **8.9 Contractors.**

N **8.9.1** Owner/operators shall ensure the requirements of Section 8.9 are met. [**652:**8.9.1]

N **8.9.2*** Only qualified contractors shall be employed for work involving the installation, repair, or modification of buildings (interior and exterior), machinery, and fire and explosion protection equipment that could adversely affect the prevention, control, or mitigation of fires and explosions. [**652:**8.9.2]

N **8.9.3* Contractor Training.**

N **8.9.3.1** Contractors operating owner/operator equipment shall be trained and qualified to operate the equipment and perform the work. [**652:**8.9.3.1]

N **8.9.3.2** Contractor training shall be documented. [**652:**8.9.3.2]

N **8.9.3.3*** Contractors working on or near a given process shall be made aware of the potential hazards from and exposures to fires and explosions. [**652:**8.9.3.3]

N **8.9.3.3.1** Contractors shall be trained on the hazards as identified in Chapter 10.

N **8.9.3.4** Contractors shall be trained and required to comply with the facility's safe work practices and policies in accordance with 10.3.2. [**652:**8.9.3.4]

N **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. [**652:**8.9.3.5]

N **8.10 Emergency Planning and Response.** Emergency planning and response shall comply with Section 10.7.

N **8.11* Incident Investigation.**

N **8.11.1*** The owner/operator shall have a system to ensure that incidents that result in a fire, deflagration, or explosion are reported and investigated in a timely manner. [**652:**8.11.1]

N **8.11.2** The investigation shall be documented and include findings and recommendations. [**652:**8.11.2]

N **8.11.3** A system shall be established to address and resolve the findings and recommendations. [**652:**8.11.3]

N **8.11.4*** The investigation findings and recommendations shall be reviewed with affected personnel. [**652:**8.11.4]

N **8.12 Management of Change.**

N **8.12.1*** Written procedures shall be established and implemented to manage proposed changes to process materials, staffing, job tasks, technology, equipment, procedures, and facilities. [**652:**8.12.1]

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

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

[**652:**8.12.2]

N **8.12.3*** Implementation of the management of change procedure shall not be required for replacements-in-kind. [**652:**8.12.3]

N **8.12.4** Design and procedures documentation shall be updated to incorporate the change. [**652:**8.12.4]

N **8.13* Documentation Retention.**

N **8.13.1** The owner/operator shall establish a program and implement a process to manage the retention of documentation, including, but not limited to, the following:

(1) Training records
(2) Equipment inspection, testing, and maintenance records
(3)* Incident investigation reports
(4) Dust hazards analyses
(5)* Process and technology information
(6)* Management of change documents
(7) Emergency response plan documents
(8)* Contractor records

[**652:**8.13.1]

N **8.14 Management Systems Review.**

N **8.14.1** The owner/operator shall evaluate the effectiveness of the management systems presented in this standard by conducting a periodic review of each management system. [**652:**8.14.1]

N **8.14.2** The owner/operator shall be responsible for maintaining and evaluating the ongoing effectiveness of the management systems presented in this standard. [**652:**8.14.2]

N **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. [**652:**8.15]

N Chapter 9 Hazard Management: Mitigation and Prevention

N **9.1* Inherently Safer Designs.**

N **9.2 Building Design.**

N **9.2.1 Risk Assessment.** A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of building design and protection features to be provided, including, but not limited to, the measures addressed in Section 9.2. [**652:**9.2.1]

N **9.2.2* Construction.** The type of construction shall be in accordance with the building code adopted by the AHJ. [**652:**9.2.2]

N **9.2.3 Building or Building Compartment Protection.**

N **9.2.3.1*** Each building or building compartment where a dust deflagration hazard exists shall be protected from the consequence of deflagration. [**652:**9.2.3.1]

N **9.2.3.2*** If a building or building compartment contains a dust explosion hazard outside of equipment, such areas shall be provided with deflagration venting to a safe area in accordance with NFPA 68. [**652:**9.2.3.2]

N **9.2.3.2.1** Venting to relieve pressure shall be located through an outside wall or roof. [**652:**9.2.3.2.1]

N **9.2.3.2.2** The fireball, blast hazards, and missile hazards that are created by deflagration venting shall not expose additional personnel or property assets. [**652:**9.2.3.2.2]

N **9.2.4 Life Safety.** Building configuration and appurtenances shall comply with the life safety requirements of the building and fire prevention codes adopted by the AHJ. [**652:**9.2.4]

N **9.2.4.1** Where a dust deflagration hazard exists in a building or building compartment outside of equipment, building configuration and appurtenances shall comply with the life safety requirements of the building and fire prevention codes for a hazardous occupancy adopted by the AHJ. [**652:**9.2.4.1]

N **9.2.4.2** Where a dust explosion hazard exists in a building or building compartment and an enclosed means of egress is provided, it shall be designed to withstand potential external overpressure from building deflagration. [**652:**9.2.4.2]

N **9.2.5 Construction Features to Limit Accumulation.**

N **9.2.5.1*** Interior surfaces where dust accumulations can occur shall be designed and constructed so as to facilitate cleaning and to minimize combustible dust accumulations. [**652:**9.2.5.1]

N **9.2.5.2** Enclosed building spaces inaccessible to routine housekeeping shall be sealed to prevent dust accumulation. [**652:**9.2.5.2]

N **9.2.5.3*** Enclosed building spaces that are difficult to access for routine housekeeping shall be designed to facilitate routine inspection for the purpose of determining the need for periodic cleaning. [**652:**9.2.5.3]

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

N **9.2.6.1** Areas where a dust deflagration hazard exists in a building or building compartment (excluding hazard within equipment) shall be segregated, separated, or detached from other occupancies to minimize damage from a fire or an explosion. [**652:**9.2.6.1]

N **9.2.6.2 Use of Segregation.**

N **9.2.6.2.1** Physical barriers erected for the purpose of limiting fire spread shall be designed in accordance with NFPA 221. [**652:**9.2.6.2.1]

N **9.2.6.2.2** Physical barriers erected to segregate fire hazard areas, including all penetrations and openings of floors, walls, ceilings, or partitions, shall have a minimum fire resistance rating based on the anticipated fire duration. [**652:**9.2.6.2.2]

N **9.2.6.2.3** Physical barriers, including all penetrations and openings of floors, walls, ceilings, or partitions, that are erected to segregate dust explosion hazard areas shall be designed to preclude failure of those barriers during a dust explosion in accordance with NFPA 68. [**652:**9.2.6.2.3]

N **9.2.6.3 Use of Separation.**

N **9.2.6.3.1*** Separation shall be permitted to be used to limit the dust explosion hazard or deflagration hazard area within a building when it is supported by a documented engineering evaluation acceptable to the AHJ. [**652:**9.2.6.3.1]

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

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

[**652:**9.2.6.3.2]

N **9.2.6.3.3** Either the separation area shall be free of dust or where dust accumulations exist on any surface, the color of the surface on which the dust has accumulated shall be readily discernible. [**652:**9.2.6.3.3]

N **9.2.6.3.4** Where separation is used to limit the dust flash-fire hazard area, in no case shall the required separation distance determined in 9.2.6.3.2 be less than 11 m (35 ft). [**652:**9.2.6.3.4]

N **9.2.6.3.5*** Where separation is used, housekeeping fixed-dust collection systems employed at points of release, and compartmentation shall be permitted to be used to limit the extent of the dust flash-fire hazard area. [**652:**9.2.6.3.5]

N **9.2.6.4 Use of Detachment.**

N **9.2.6.4.1** Detachment shall be permitted to be used to limit the dust hazard area to a physically separated adjacent building. [**652:**9.2.6.4.1]

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

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

[**652:**9.2.6.4.2]

N **9.2.7* Additional Facility Design Requirements for All Metals.**

N **9.2.7.1 General.**

N **9.2.7.1.1** In addition to the requirements of this chapter, buildings shall comply with the applicable provisions of locally adopted building and fire safety codes.

N **9.2.7.1.2** Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes if a hazard analysis is conducted to ensure the modifications do not create a greater risk.

N **9.2.7.1.3** Installation of automatic sprinkler protection, where used, shall comply with Chapter 10.

N **9.2.7.1.4** 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.

N **9.2.7.1.5** Fuel supply lines shall have an emergency shutoff valve located within easy access outside of the building.

N **9.2.7.1.6** Emergency shutoff valves shall be clearly identified.

N **9.2.7.1.7** 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.

N **9.2.7.1.8** One or more remotely located control stations shall be provided to allow the selective shutdown of process equipment in an emergency.

N **9.2.7.2 Building Location, Separation, and Segregation.**

N **9.2.7.2.1** 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.

N **9.2.7.2.2** 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.

N **9.2.7.2.3** 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.

N **9.2.7.2.4** The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

N **9.2.7.2.5** All doors in fire-rated walls and partitions shall be listed, self-closing fire doors installed in accordance with NFPA 80.

N **9.2.7.3 Building Construction.**

N **9.2.7.3.1 Noncombustible Construction.**

N **9.2.7.3.1.1** Paragraph 9.2.7.3 shall apply to buildings or portions of buildings that are dedicated to the handling, processing, or storage of metal in combustible or molten form.

N **9.2.7.3.1.2** Buildings dedicated to the storage, handling, processing, or use of combustible metals shall be constructed of noncombustible materials, unless a hazard analysis has been performed that shows that noncombustible construction is not required.

N **9.2.7.3.1.3** Buildings housing furnaces, boring and crushing facilities, and refining operations shall be constructed of noncombustible materials.

N **9.2.7.3.1.4** Construction of other than noncombustible materials shall be permitted if equivalent protection can be demonstrated.

N **9.2.7.3.2 Roofs, Ceilings, and Walls.**

N **9.2.7.3.2.1*** Roof decks shall be watertight.

N **9.2.7.3.2.2** 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.

N **9.2.7.3.2.3** Walls and ceilings shall be constructed with noncombustible insulation that has been tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C.*

N **9.2.7.3.2.4** 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.

N **9.2.7.3.2.5** The requirements of 9.2.7.3.2.4 shall also apply to elevated platforms, balconies, floors, and gratings.

N **9.2.7.3.3 Floors and Surfaces.**

N **9.2.7.3.3.1** 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.

N **9.2.7.3.3.2** The floor shall be capable of providing containment of molten metals resulting from fire.

N **9.2.7.3.3.3** 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.

N **9.2.7.3.3.4** Floors in reduction, boring, and crushing buildings shall be made of noncombustible materials, such as concrete, brick, or steel plate.

N **9.2.7.3.3.5** Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate firefighting operations.

N **9.2.7.3.3.6** The buildings shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

N **9.2.7.3.3.7*** 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.

N **9.2.7.4* Ventilation, Heating, and Cooling.**

N **9.2.7.4.1** Where hydrogen generation occurs during the process, ventilation shall be provided for the dissipation of hydrogen to the atmosphere.

N **9.2.7.4.2** Mechanical ventilation systems shall be designed and installed in accordance with the locally adopted building and fire code.

N **9.2.7.4.3** 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.

N **9.2.7.4.3.1** 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.

N **9.2.7.4.3.2** Fans or blowers used to convey the heated or cooled air shall be located in a combustible metal dust-free location.

N **9.2.7.4.3.3** The air supply shall be taken from outside or from a location that is free of combustible metal dust.

N **9.2.7.4.3.4** 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.

N **9.2.7.4.3.5** The requirements of 9.2.7.4.3.1 through 9.2.7.4.3.4 shall not apply to areas where metal is melted.

N **9.2.7.5 Explosion Mitigation/Deflagration Venting.**

N **9.2.7.5.1*** Explosion 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 hazard analysis has been performed that shows that explosion venting is not required.

N **9.2.7.5.2** 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.

N **9.2.7.5.3*** 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.

N **9.2.7.5.4** Equipment shall be located or arranged in a manner that minimizes combustible dust accumulation on surfaces.

N **9.2.7.5.5** Deflagration venting shall not be required for areas where combustible metal powder is stored or moved only in covered or sealed containers.

N **9.2.7.5.6*** 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.

N **9.2.7.6* Grounding and Bonding.** All process equipment and all building steel shall be bonded and grounded in accordance with *NFPA 70*.

N **9.2.7.7 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.

N **9.2.8 Additional Facility Design Requirements for Legacy Metals.**

N **9.2.8.1 General.**

N **9.2.8.1.1** 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 standard.

N **9.2.8.1.2** In addition to the requirements of this chapter, buildings shall comply with the applicable provisions of locally adopted building and fire safety codes.

N **9.2.8.1.3** Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes if a hazard analysis is conducted to ensure the modifications do not create a greater risk.

N **9.2.8.2 Building Location, Separation, and Segregation.**

N **9.2.8.2.1** Separate buildings shall be required where different operations, including, but not limited to, atomization, grinding, crushing, screening, blending, or packaging, are performed.

N **9.2.8.2.2** More than one operation within the same building shall be permitted if the design provides equivalent protection.

N **9.2.8.2.3** Different production operations, including drying rooms, shall be located in separate but not adjoining buildings that are located at least 15 m (50 ft) from each other.

N **9.2.8.2.4** Two buildings less than 15 m (50 ft) apart shall be permitted if the wall facing the exposed building is capable of resisting a blast with a gauge pressure of 13.8 kPa (2.0 psi) and is non-load-bearing, noncombustible, and without openings.

N **9.2.8.2.5** 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 90.9 m (300 ft) 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.

N **9.2.8.2.6** 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.

N **9.2.8.2.7** 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.

N **9.2.8.3 Separation from Water.**

N **9.2.8.3.1** Combustible metal winning, refining, and casting operations shall be protected from rain and other possible sources of inadvertent contact with water.

N **9.2.8.3.2** Water leakage inside or into any building where the water can contact water-reactive combustible metal shall be prevented.

N **9.2.8.3.3*** 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.

N **9.2.8.3.4** Piping permitted by 9.2.8.3.3 shall be equipped with an emergency shutoff that is identified and located outside the area.

N **9.2.8.3.5** 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.

N **9.3 Equipment Design.**

N **9.3.1* Risk Assessment.** A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of protection to be provided, including, but not limited to, protection measures addressed in Section 9.3. [**652:**9.3.1]

N **9.3.2 Design for Dust Containment.**

N **9.3.2.1** All components of enclosed systems that handle combustible particulate solids shall be designed to prevent the escape of dust, except for openings intended for intake and discharge of air and material. [**652:**9.3.2.1]

N **9.3.2.2** Where the equipment cannot be designed for dust containment, dust collection shall be provided. *(See also 9.3.3.)* [**652:**9.3.2.2]

N **9.3.3 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems.** Pneumatic conveying, dust collection, and centralized vacuum cleaning systems shall comply with Chapter 13.

N **9.3.4 AMS.** AMS shall comply with Chapter 13.

N **9.3.5 Air-Moving Devices (Fans and Blowers).** Air-moving devices shall comply with Chapter 13.

N **9.3.6 Duct Systems.** Duct systems shall comply with Chapter 13.

N **9.3.7 Sight Glasses.** Sight glasses shall not be permitted to be used in pneumatic conveying systems for combustible metals.

N **9.3.8 Abort Gates/Dampers.**

N **9.3.8.1 Construction.**

N **9.3.8.1.1** Abort gates and abort dampers shall be constructed of noncombustible materials. [**652:**9.3.8.1.1]

N **9.3.8.1.2** Abort gates and abort dampers shall be actuated by spark detection or equivalent automatic detection in the duct or pipe upstream of the device. [**652:**9.3.8.1.2]

N **9.3.8.1.3** The detection system and abort gate shall respond to prevent sparks, glowing embers, or burning materials from passing beyond the abort gate. [**652:**9.3.8.1.3]

N **9.3.8.1.4** The abort gate or abort damper shall be installed so that it diverts airflow to a restricted area to safely discharge combustion gases, flames, burning solids, or process gases or fumes. [**652:**9.3.8.1.4]

N **9.3.8.2 Manual Reset.**

N **9.3.8.2.1** An abort gate or abort damper shall be provided with a manually activated reset located proximate to the device such that, subsequent to operation, it can be returned to the normal operating position at the damper/gate. [**652:**9.3.8.2.1]

N **9.3.8.2.2** Automatic or remote reset provisions shall not be permitted. [**652:**9.3.8.2.2]

N **9.3.8.3 Integrity of Actuation Circuits.**

N **9.3.8.3.1** All fire protection abort gates or abort dampers shall be connected to the fire detection control panel via Class A or Class D circuits as described in *NFPA 72*. [**652:**9.3.8.3.1]

N **9.3.8.3.2** When the abort gate is connected via a Class A circuit, supervision shall include the continuity of the abort gate or abort damper releasing device, whether that device is a solenoid coil, a detonator (explosive device) filament, or other such device. [**652:**9.3.8.3.2]

N **9.3.9 Bulk Storage Enclosures.**

N **9.3.9.1 General.**

N **9.3.9.1.1** For the purposes of this section, bulk storage enclosures shall include items such as bins, tanks, hoppers, and silos. [**652:**9.3.9.1.1]

N **9.3.9.1.2*** The requirements of this section shall not apply to containers that are used for transportation of the material. [**652:**9.3.9.1.2]

N **9.3.9.2* Construction.** Bulk storage enclosures, whether located inside or outside of buildings, shall be constructed so as not to represent an increase in the fire load beyond the capabilities of the existing fire protection. [**652:**9.3.9.2]

N **9.3.9.3 Fixed Bulk Storage Location.**

N **9.3.9.3.1** Where an explosion hazard exists, fixed bulk storage enclosures shall be located outside of buildings. [**652:**9.3.9.3.1]

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

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

[**652:**9.3.9.3.2]

N **9.3.9.4* Interior Surfaces.** Interior surfaces shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulation. [**652:**9.3.9.4]

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

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

[**652:**9.3.9.5]

N **9.3.10* Size Reduction.**

N **9.3.10.1** Before material is processed by size reduction equipment, foreign materials shall be excluded or removed as required by 9.4.12. [**652:**9.3.10]

N **9.3.10.2** Size reduction shall also meet the requirements of applicable chapters of this standard.

N **9.3.11* Particle Size Separation.**

N **9.3.11.1** Particle separation devices shall be designed to control fugitive dust emissions per Section 9.6. [**652:**9.3.11.1]

N **9.3.11.2** Flexible connectors shall be in conformance with 9.3.6. [**652:**9.3.11.2]

N **9.3.12 Pressure Protection Systems.**

N **9.3.12.1 Vacuum Breakers.** Vacuum breakers shall be installed on negative-pressure systems if the enclosure is not designed for the maximum vacuum attainable. [**652:**9.3.12.1]

N **9.3.12.2 Pressure Relief Devices.**

N **9.3.12.2.1** Pressure relief devices for relief of pneumatic overpressure shall be installed on positive-pressure systems. [**652:**9.3.12.2.1]

N **9.3.12.2.2** The requirement of 9.3.12.2.1 shall not apply to systems that are designed for a gauge pressure of less than 103 kPa (15 psi) 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*. [**652:**9.3.12.2.2]

N **9.3.12.2.3** The requirement of 9.3.12.2.1 shall not apply to systems that are designed for a gauge pressure of less than

103 kPa (15 psi) and are capable of containing the maximum pressure attainable. [**652:**9.3.12.2.3]

N **9.3.12.2.4*** Pressure relief devices shall not be vented to an area where a dust explosion hazard or dust flash-fire hazard exists in accordance with 7.3.3.4. [**652:**9.3.12.2.4]

N **9.3.12.3 Airflow Control Valves.**

N **9.3.12.3.1** Airflow control valves that are installed in pneumatic conveying, dust collection, or centralized vacuum cleaning systems shall provide a tight shutoff. [**652:**9.3.12.3.1]

N **9.3.12.3.2** Airflow control valves shall be sized to allow passage of the design airflow when the valve is fully open. [**652:**9.3.12.3.2]

N **9.3.12.3.3** The position of airflow control valves shall be visually indicated. [**652:**9.3.12.3.3]

N **9.3.12.3.4** Manually adjusted airflow control valves, dampers, or gates, shall have a means of being secured so as to prevent subsequent adjustment or manipulation once the system is set. [**652:**9.3.12.3.4]

N **9.3.12.3.5** Diverter valves shall effect a positive diversion of the material and shall mechanically seal all other directions from air or material leakage. [**652:**9.3.12.3.5]

N **9.3.13 Material Feeding Devices.**

N **9.3.13.1 Material Feeding Devices.**

N **9.3.13.1.1** Mechanical feeding devices shall be equipped with a shear pin or overload detection device and alarm. [**652:**9.3.13.1.1]

N **9.3.13.1.2** The alarm shall sound at the operator control station. [**652:**9.3.13.1.2]

N **9.3.13.2 Drives.**

N **9.3.13.2.1** All drives used in conjunction with feeders, air locks, and other material feeding devices shall be directly connected. [**652:**9.3.13.2.1]

N **9.3.13.2.2** Belt, chain and sprocket, or other indirect drives that are designed to stall the driving forces without slipping and to provide for the removal of static electric charges shall be permitted to be used. [**652:**9.3.13.2.2]

N **9.3.14* Bucket Elevators.**

N **9.3.14.1** Elevator casings, head and boot sections, and connecting ducts shall be designed to control fugitive dust emissions and shall be constructed of noncombustible materials. [**652:**9.3.14.1]

N **9.3.14.2** Where provided, inlet and discharge hoppers shall be designed to be accessible for cleaning and inspection. [**652:**9.3.14.2]

N **9.3.14.3 Power Cutoff.**

N **9.3.14.3.1** Each leg shall be provided with a speed sensor device that will cut off the power to the drive motor and actuate an alarm in the event the leg belt slows to 80 percent of normal operating speed. [**652:**9.3.14.3.1]

N **9.3.14.3.2** Feed to the elevator leg by mechanical means shall be stopped or diverted. [**652:**9.3.14.3.2]

N **9.3.14.4 Belts.**

N **9.3.14.4.1*** Belt-driven bucket elevators shall have nonslip material (lagging) installed on the head pulley to minimize slippage. [**652:**9.3.14.4.1]

N **9.3.14.4.2*** Belts and lagging shall be static dissipative and fire resistant. [**652:**9.3.14.4.2]

N **9.3.14.4.3** No bearings shall be located in the bucket elevator casing. [**652:**9.3.14.4.3]

N **9.3.14.4.4*** Head and boot sections shall be provided with openings to allow for cleanout, inspection, and alignment of the pulley and belt. [**652:**9.3.14.4.4]

N **9.3.14.5 Drive.**

N **9.3.14.5.1*** The bucket elevator shall be driven by a motor and drive train that is capable of handling the full-rated capacity of the elevator without overloading. [**652:**9.3.14.5.1]

N **9.3.14.5.2** The drive shall be capable of starting the unchoked elevator under full (100 percent) load. [**652:**9.3.14.5.2]

N **9.3.14.6 Monitors.**

N **9.3.14.6.1** Elevators shall have monitors at head and tail pulleys that indicate high bearing temperature, pulley alignment, and belt alignment. [**652:**9.3.14.6.1]

N **9.3.14.6.2** Abnormal conditions shall actuate an alarm requiring corrective action. [**652:**9.3.14.6.2]

N **9.3.14.6.3** The alarm specified in 9.3.14.6.2 shall sound at the operator control station. [**652:**9.3.14.6.3]

N **9.3.14.7 Emergency Controls.**

N **9.3.14.7.1** All bins into which material is directly discharged from the bucket elevator and that are not designed with automatic overflow systems shall be equipped with devices to shut down equipment or with high-level indicating devices with visual or audible alarms. [**652:**9.3.14.7.1]

N **9.3.14.7.2** The audible alarm specified in 9.3.14.7.1 shall sound at the operator control station. [**652:**9.3.14.7.2]

N **9.3.15* Enclosed Conveyors.**

N **9.3.15.1 Housing and Coverings.**

N **9.3.15.1.1** Housings for enclosed conveyors (e.g., screw conveyors and drag conveyors) shall be of metal construction and designed to prevent escape of combustible dusts. [**652:**9.3.15.1.1]

N **9.3.15.1.1.1** Flexible screw conveyors shall not be permitted to be used with metal dusts or powders.

N **9.3.15.1.2** Coverings on cleanout, inspection, and other openings shall be fastened to prevent the escape of combustible dusts. [**652:**9.3.15.1.2]

N **9.3.15.2 Power Shutoff.**

N **9.3.15.2.1*** All conveyors shall be equipped with a device that shuts off the power to the drive motor and sounds an alarm in the event the conveyor plugs. [**652:**9.3.15.2.1]

N **9.3.15.2.2** The alarm specified in 9.3.15.2.1 shall alert operators, and feed to the conveyor shall be stopped or diverted. [**652:**9.3.15.2.2]

N **9.3.16 Mixers and Blenders.**

N **9.3.16.1** Mixers and blenders shall be designed to control fugitive dust emissions. [**652:**9.3.16.1]

N **9.3.16.2** Foreign materials shall be excluded or removed as required by 9.4.12. [**652:**9.3.16.2]

N **9.3.16.3** Mixers and blenders shall be made of metal, other noncombustible material, or material that does not represent an increased fire load beyond the capabilities of the existing fire protection. [**652:**9.3.16.3]

N **9.3.17* Dryers.** Drying of legacy metals shall comply with the requirements in Chapter 17.

N **9.3.17.1 Drying Media.**

N **9.3.17.1.1** Drying media that come into contact with material being processed shall not be recycled to rooms or buildings. [**652:**9.3.17.1.1]

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

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

[**652:**9.3.17.1.2]

N **9.3.17.1.3** Dryers shall be constructed of noncombustible materials. [**652:**9.3.17.1.3]

N **9.3.17.1.4** Interior surfaces of dryers shall be designed so that accumulations of material are minimized and cleaning is facilitated. [**652:**9.3.17.1.4]

N **9.3.17.1.5** Access doors or openings shall be provided in all parts of the dryer and connecting conveyors to permit inspection, cleaning, maintenance, and the effective use of portable extinguishers or hose streams. [**652:**9.3.17.1.5]

N **9.3.17.1.6** Heated dryers shall comply with NFPA 86. [**652:**9.3.17.1.6]

N **9.3.17.1.7*** Heated dryers shall have operating controls arranged to maintain the temperature of the drying chamber within the prescribed limits. [**652:**9.3.17.1.7]

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

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

[**652:**9.3.17.1.8]

N **9.3.18 Transfer Points. (Reserved)**

N **9.4 Ignition Source Control.**

N **9.4.1* Retroactivity.** Unless otherwise specified, the requirements of Section 9.4 shall be applied retroactively. [**652:**9.4.1]

N **9.4.2* Risk Assessment.** A documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be conducted to determine the level of ignition source control to be provided including, but not limited to, the controls addressed in Section 9.4. [**652:**9.4.2]

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

N **9.4.4 Hot Surfaces.**

N **9.4.4.1 Retroactivity.** This section shall not be required to be applied retroactively. [**652:**9.4.4]

N **9.4.4.2*** Heated external surfaces of process equipment and piping in dust deflagration hazard areas shall be maintained at a temperature at least 50°C (112°F) below the dust layer and dust cloud ignition temperatures measured in a standardized test acceptable to the AHJ. [**652:**9.4.4.2]

N **9.4.5 Bearings.**

N **9.4.5.1 Retroactivity.** This section shall not be required to be applied retroactively. [**652:**9.4.5.1]

N **9.4.5.2** Bearings shall also comply with 12.3.1.

N **9.4.5.3*** 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. [**652:**9.4.5.2]

N **9.4.5.4** The owner/operator shall establish frequencies for monitoring bearings in 9.4.5.3. [**652:**9.4.5.3]

N **9.4.5.5*** It shall be permitted to eliminate bearing monitoring based on a risk assessment acceptable to the AHJ. [**652:**9.4.5.4]

N **9.4.6 Hazardous (Classified) Locations for Electrical Installations.** See Section 12.4 for Hazardous (classified) locations for electrical installations.

N **9.4.7* Electrostatic Discharges.**

N **9.4.7.1* General Requirements.**

N **9.4.7.1.1*** 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.

N **9.4.7.1.1.1** Grounding and bonding of equipment shall be independent of the facility electrical system.

N **9.4.7.1.1.2*** Where nonconductive components present a discontinuity in the electrical path, isolated conductive components shall be bonded.

N **9.4.7.1.2*** Movable or mobile process equipment or tools of metal construction shall be bonded or grounded or both, prior to use.

N **9.4.7.1.3*** 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.

N **9.4.7.1.4** Static dissipative belts shall be used on belt-driven equipment.

N **9.4.7.1.5** Bonding and grounding for dust collection and pneumatic conveying shall be in accordance with Chapter 13.

N **9.4.7.1.6* Grounding of Personnel.**

N **9.4.7.1.6.1** 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.

N **9.4.7.1.6.2** 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 (MIE) of the dust cloud is greater than 30 mJ.

N **9.4.7.2 Spark-Resistant Tools.**

N **9.4.7.2.1*** 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.

N **9.4.7.2.2*** 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.

N **9.4.7.2.3** 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.

N **9.4.7.3 Conductive Equipment.**

N **9.4.7.3.1** Particulate handling equipment shall be conductive unless the provisions of 9.4.7.3.2 are applicable. [**652:**9.4.7.1.1]

N **9.4.7.3.2** Nonconductive system components shall be permitted where all of the following conditions are met:

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

[**652:**9.4.7.1.2]

N **9.4.7.3.3*** Bonding and grounding with a resistance of less than 1.0×10^6 ohms to ground shall be provided for conductive components. [**652:**9.4.7.1.3]

N **9.4.7.3.4* Flexible Connectors.**

N **9.4.7.3.4.1* Retroactivity.** This section shall not be required to be applied retroactively. [**652:**9.4.7.1.4.1]

N **9.4.7.3.4.2** Flexible connectors shall comply with 9.4.7.1.1.2.

N **9.4.7.3.4.3*** Where flammable vapors are not present, flexible connectors with a resistance equal to or greater than 1.0×10^8 ohms shall be permitted under either of the following conditions:

(1) The dust has an MIE greater than 2000 mJ.
(2) The maximum powder transfer velocity is less than 10 m/sec (200 fpm).

[**652:**9.4.7.1.4.3]

N **9.4.7.4 Maximum Particulate Transport Rates.**

N **9.4.7.4.1*** The maximum particulate transport rates in 9.4.7.4.3 shall apply when the volume of the vessel being filled is greater than 1 m^3 (35 ft^3) and a single feed stream to the vessel meets both of the following conditions:

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

[**652:**9.4.7.2.1]

N **9.4.7.4.2*** The maximum particulate transport rate in 9.4.7.4.3 shall apply when the volume of the vessel being filled is greater than 1 m^3 (35 ft^3) and either of the following conditions is met:

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

[**652:**9.4.7.2.2]

N **9.4.7.4.3*** Where the conditions of 9.4.7.4.1 or 9.4.7.4.2 are met, the maximum permitted material transport rate of particles shall be limited by the following:

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

[**652:**9.4.7.2.3]

N **9.4.7.5* Grounding of Personnel.**

N **9.4.7.5.1*** Where an explosive atmosphere exists and is subject to ignition from an electrostatic spark discharge from ungrounded personnel, personnel involved in manually filling or emptying particulate containers or vessels shall be grounded during such operations. [**652:**9.4.7.3.1]

N **9.4.7.5.2** 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.

[**652:**9.4.7.3.2]

N **9.4.7.6* Flexible Intermediate Bulk Containers (FIBCs).** FIBCs shall be permitted to be used for the handling and storage of combustible particulate solids in accordance with the requirements in 9.4.7.6.2 through 9.4.7.6.8. [**652:**9.4.7.4]

N **9.4.7.6.1** FIBCs shall not be permitted to be used for the handling and storage of legacy metals except for aluminum.

N **9.4.7.6.2*** Electrostatic ignition hazards associated with the particulate and objects surrounding or inside the FIBC shall be included in the DHA required in Chapter 7. [**652:**9.4.7.4.1]

N **9.4.7.6.3*** Type A FIBCs shall be limited to use with noncombustible particulate solids or combustible particulate solids having an MIE greater than 1000 mJ. [**652:**9.4.7.4.2]

N **9.4.7.6.3.1** Type A FIBCs shall not be used in locations where flammable vapors are present. [**652:**9.4.7.4.2.1]

N **9.4.7.6.3.2*** Type A FIBCs shall not be used with conductive dusts. [**652:**9.4.7.4.2.2]

N **9.4.7.6.4*** Type B FIBCs shall be permitted to be used where combustible dusts having an MIE greater than 3 mJ are present. [**652:**9.4.7.4.3]

N **9.4.7.6.4.1** Type B FIBCs shall not be used in locations where flammable vapors are present. [**652:**9.4.7.4.3.1]

N **9.4.7.6.4.2** Type B FIBCs shall not be used for conductive dusts. *(See A.9.4.7.6.3.2.)* [**652:**9.4.7.4.3.2]

N **9.4.7.6.5*** Type C FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I Division Group C/D or Zone Group IIA/IIB flammable vapors or gases, as defined by *NFPA 70*, are present. [**652:**9.4.7.4.4]

N **9.4.7.6.5.1** Conductive FIBC elements shall terminate in a grounding tab, and resistance from these elements to the tab shall be or less than or equal to 10^7 ohms. [**652:**9.4.7.4.4.1]

N **9.4.7.6.5.2** Type C FIBCs shall be grounded during filling and emptying operations with a resistance to ground of less than 25 ohms. [**652:**9.4.7.4.4.2]

N **9.4.7.6.5.3** Type C FIBCs shall be permitted to be used for conductive dusts where a means for grounding the conductive dusts is present. [**652:**9.4.7.4.4.3]

N **9.4.7.6.6*** Type D FIBCs shall be permitted to be used with combustible particulate solids and in locations where Class I Division Group C/D or Zone Group IIA /IIB flammable vapor or gases, as defined by *NFPA 70*, having an MIE greater than 0.14 mJ are present. [**652:**9.4.7.4.5]

N **9.4.7.6.6.1*** Type D FIBCs shall not be permitted to be used for conductive particulate solids. [**652:**9.4.7.4.5.1]

N **9.4.7.6.7*** 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. [**652:**9.4.7.4.6]

N **9.4.7.6.7.1** Intended use shall include both the product being handled and the environment in which the FIBC will be used. [**652:**9.4.7.4.6.1]

N **9.4.7.6.7.2** 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. [**652:**9.4.7.4.6.2]

N **9.4.7.6.7.3** Documentation of test results shall be made available to the AHJ. [**652:**9.4.7.4.6.3]

N **9.4.7.6.7.4** FIBCs that have not been tested and verified for type in accordance with IEC 61340-4-4, *Electrostatics — Part 4-4: Standard Test Methods for Specific Applications — Electrostatic Classification of Flexible Intermediate Bulk Containers (FIBC)*, shall not be used for combustible dusts or in flammable vapor atmospheres. [**652:**9.4.7.4.6.4]

N **9.4.7.6.8*** Deviations from the requirements in 9.4.7.6.2 through 9.4.7.6.7 for safe use of FIBCs shall be permitted based on a documented risk assessment acceptable to the AHJ. [**652:**9.4.7.4.7]

N **9.4.7.7 Rigid Intermediate Bulk Containers (RIBCs).**

N **9.4.7.7.1*** 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. [**652:**9.4.7.5.1]

N **9.4.7.7.2*** Nonconductive RIBCs shall not be permitted to be used for applications, processes, or operations involving combustible particulate solids or where flammable vapors or gases are present unless a documented risk assessment assessing the electrostatic hazards is acceptable to the AHJ. [**652:**9.4.7.5.2]

N **9.4.8 Open Flames and Fuel-Fired Equipment.**

N **9.4.8.1*** Production, maintenance, or repair activities that can release or lift combustible dust shall not be conducted within 11 m (35 ft) of an open flame or pilot flame. [**652:**9.4.8.1]

N **9.4.8.2** Fuel-fired space heaters drawing local ambient air shall not be located within a Class II hazardous (classified) area. [**652:**9.4.8.2]

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

(1) NFPA 31
(2) NFPA 54
(3) NFPA 85
(4) NFPA 86

[**652:**9.4.8.3]

N **9.4.8.4** Inspections and preventive maintenance for fuel fired process equipment shall include verification that there are no significant combustible dust accumulations within or around the equipment. [**652:**9.4.8.4]

N **9.4.8.5** Unless the equipment is operated within the limits of 9.4.4.2, provisions shall be made to prevent the accumulation of combustible dust on heated surfaces of heating units. [**652:**9.4.8.5]

N **9.4.8.6** In facility locations where airborne dust or dust accumulations on horizontal surfaces are apt to occur, heating units shall be provided with a source of combustion air ducted directly from the building exterior or from an unclassified location. [**652:**9.4.8.6]

N **9.4.9 Industrial Trucks.**

N **9.4.9.1** Industrial trucks shall be listed or approved for the electrical classification of the area, as determined by 9.4.6, and shall be used in accordance with NFPA 505. [**652:**9.4.9.1]

N **9.4.9.2*** Where industrial trucks in accordance with NFPA 505 are not commercially available, a documented risk assessment shall be permitted to be used to specify the fire and explosion prevention features for the equipment being used. [**652:**9.4.9.2]

N **9.4.10 Process Air and Media Temperatures.**

N **9.4.10.1*** Heated process equipment containing combustible dust shall have operating controls arranged to maintain the temperature of equipment interiors within the prescribed limits. [**652:**9.4.10.1]

N **9.4.11 Self-Heating.**

N **9.4.11.1*** Material in silos and other large storage piles of particulates prone to self-heating shall be managed to control self-heating or have self-heating detection provisions. [**652:**9.4.11.1]

N **9.4.11.2** Where a self-heating hazard is identified, provisions shall be in place for managing the consequences of self-heating in storage silos or bins. [**652:**9.4.11.2]

N **9.4.12 Friction and Impact Sparks.**

N **9.4.12.1** Means shall be provided to prevent foreign material from entering the system when such foreign material presents an ignition hazard. [**652:**9.4.12.1]

N **9.4.12.2*** Foreign materials, such as tramp metal, that are capable of igniting combustible material being processed shall be removed from the process stream. [**652:**9.4.12.2]

N **9.4.12.3** Tramp materials that present an ignition potential shall be permitted to be in the material inlet stream if the equipment is provided with explosion protection. [**652:**9.4.12.3]

N **9.4.12.4*** Clearances and alignment of high-speed moving parts in equipment that is processing combustible particulates shall be checked at intervals established by the owner/operator based on wear experience unless the equipment is equipped with vibration monitors and alarms or routine manual monitoring is performed. [**652:**9.4.12.4]

N **9.4.12.5** The alignment and clearance of buckets in elevators that are transporting combustible particulates shall be checked at intervals established by the owner/operator based on facility wear experience unless the elevators are equipped with belt alignment monitoring devices. [**652:**9.4.12.5]

N **9.4.13 Propellant-Actuated Tools.**

N **9.4.13.1*** Propellant-actuated tools shall not be used in areas where a dust explosion can occur unless all machinery in the area is shut down and the area and machinery are properly cleaned.

N **9.4.13.2** Propellant-actuated tools shall be used in accordance with Section 12.2.

N **9.4.14 Electrical Power and Control.**

N **9.4.14.1** All electrical equipment and wiring shall be installed in accordance with *NFPA 70*.

N **9.4.14.2** All process equipment and all building steel shall be bonded and grounded in accordance with *NFPA 70*.

N **9.4.14.3** All manufacturing buildings shall be provided with emergency lighting systems in accordance with NFPA *101*.

N **9.4.14.4** Control equipment, control rooms, and offices meeting the requirements of NFPA 496 shall be permitted.

N **9.4.14.5** Preventive maintenance for electrical equipment shall be established commensurate with the environment and conditions.

N **9.4.14.6** One or more remotely located control stations shall be provided to allow the safe and selective shutdown of process equipment in an emergency.

N **9.4.14.7** 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.

N **9.4.14.8** Where process equipment presents an internal deflagration hazard, an interlock shall prevent equipment operation unless associated access panels are fully closed.

N **9.4.15 Smoking.**

N **9.4.15.1*** Smoking shall not be permitted in areas where metals in a combustible form are present.

N **9.4.15.2** Smoking materials, matches, and lighters shall not be carried or used by employees or visitors in areas where metals in a combustible form are present.

N **9.4.15.3** The use of electronic cigarettes (vaping) shall be in accordance with Section 12.5.

N **9.4.15.4** Smoking shall be permitted only in designated areas.

N **9.4.15.5** No-smoking areas shall be posted with “No Smoking” signs.

N **9.4.15.6** Where smoking is prohibited throughout an entire plant, the use of signage shall be at the discretion of the facility management.

N **9.4.16 Additional Requirements.** In addition to the requirements in Section 9.4, the requirements in Chapter 12 shall also apply.

N **9.5 Pyrophoric Dusts. (Reserved)**

N **9.6 Dust Control.**

N **9.6.1*** Continuous suction or some other means to control fugitive dust emissions shall be provided for processes where combustible dust is liberated in normal operation. [**652:**9.6.1]

N **9.6.1.1** Where continuous suction is used, the dust shall be conveyed to air–material separators designed in accordance with 9.3.2. [**652:**9.6.1.1]

N **9.6.2 Liquid Dust Suppression Methods for Dust Control.** Liquid dust suppression methods shall not be used with combustible metals unless acceptable through the DHA.

N **9.6.3* Fans for Continuous Dust Control.** It shall be permitted to install and use fans to limit dust accumulation in elevated areas that are otherwise difficult to reach for housekeeping. [**652:**9.6.3]

N **9.6.3.1** Fans shall be appropriate for the electrical classification in the areas where they are used. [**652:**9.6.3.1]

N **9.6.3.2** Fans shall be provided in sufficient numbers and locations as required to keep the target areas free of dust accumulations. [**652:**9.6.3.2]

N **9.6.3.3** Fans shall be in operation whenever the equipment generating the dusts is in operation. [**652:**9.6.3.3]

N **9.6.3.4** Fans shall be interlocked to automatically shut down in the event of sprinkler system operation. [**652:**9.6.3.4]

N **9.6.3.5** Dust dispersed by the fans shall not create an explosible dust cloud. [**652:**9.6.3.5]

N **9.6.3.6** The location and range of motion of the fans shall be designed to prevent flow impingement on floors or open equipment containing entrainable dust. [**652:**9.6.3.6]

N **9.6.3.7** Areas that will be swept by the fans shall be free of dust accumulations prior to placing the fans in operation and after every shutdown. [**652:**9.6.3.7]

N **9.6.3.8*** These fans shall be used in conjunction with the housekeeping program to remove dust from the facility. [**652:**9.6.3.8]

N **9.6.3.9*** Concealed spaces, such as areas above suspended ceilings, shall be sealed to prevent dust accumulation. [**652:**9.6.3.9]

N **9.6.3.10** These systems shall not be used where areas above suspended ceilings are used as return air plenums for HVAC systems. [**652:**9.6.3.10]

N **9.6.3.11** Periodic inspections shall be performed to ensure that dust accumulations are maintained below the threshold dust layer thicknesses determined in 11.4. [**652:**9.6.3.11]

N **9.6.4 Additional Requirements.** In addition to the requirements in Section 9.6, the requirements in Chapter 13 shall also apply.

N **9.7 Explosion Prevention/Protection.**

N **9.7.1 General.** Where a dust explosion hazard exists within an enclosure, measures shall be taken as specified in Section 9.7 to protect personnel from the consequences of a deflagration in that enclosure. [**652:**9.7.1]

N **9.7.2 Risk Assessment.** A documented risk assessment acceptable to the AHJ shall be permitted to be conducted to determine the level of protection to be provided, including, but not limited to, the measures addressed in Section 9.7. [**652:**9.7.2]

N **9.7.3 Equipment Protection.**

N **9.7.3.1* General.** Where an explosion hazard exists within any operating equipment greater than 0.2 m^3 (8 ft^3) of containing volume, the equipment shall be protected from the effects of a deflagration. [**652:**9.7.3.1]

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

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

[**652:**9.7.3.2]

N **9.7.3.3*** 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.

N **9.7.3.4** Enclosures and all interconnections protected in accordance with 9.7.3.2 shall be designed to withstand the resultant pressures produced during the deflagration event. [**652:**9.7.3.3]

N **9.7.4* Equipment Isolation.**

N **9.7.4.1** Where a dust explosion hazard exists, isolation devices shall be provided in accordance with NFPA 69 to prevent deflagration propagation between connected equipment. [**652:**9.7.4.1]

N **9.7.4.2** Isolation devices shall not be required where oxidant concentration has been reduced in accordance with 9.7.3.2(1) or where the dust has been rendered noncombustible in accordance with 9.7.3.2(6). [**652:**9.7.4.2]

N **9.7.4.3** Where a dust explosion hazard exists, isolation devices shall be provided in accordance with NFPA 69 to prevent deflagration propagation from equipment through ductwork to the work areas. [**652:**9.7.4.3]

N **9.8 Fire Protection.**

N **9.8.1 General.** In addition to the requirements in Section 9.8, the requirements in Chapter 10 shall also apply.

N **9.8.2 Fire Extinguishers.**

N **9.8.2.1** Portable fire extinguishers shall be provided throughout all buildings in accordance with the requirements of NFPA 10. [**652:**9.8.3.1]

N **9.8.2.2*** 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. [**652:**9.8.3.2]

N **9.8.3 Hose, Standpipes, Hydrants, and Water Supply.** The requirements in 9.8.3 shall apply where water has been deemed an acceptable extinguishing agent.

N **9.8.3.1** Standpipes and hose, where provided, shall comply with NFPA 14. [**652:**9.8.4.1]

N **9.8.3.2 Nozzles.**

N **9.8.3.2.1*** Portable spray hose nozzles that are listed or approved for use on Class C fires shall be provided in areas that contain dust, to limit the potential for generating unnecessary airborne dust during fire-fighting operations. [**652:**9.8.4.2.1]

N **9.8.3.2.2*** 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. [**652:**9.8.4.2.2]

N **9.8.3.2.3** It shall be permitted to use straight stream nozzles or combination nozzles to reach fires in locations that are otherwise inaccessible with nozzles specified in 9.8.3.2.1. [**652:**9.8.4.2.3]

N **9.8.3.3 Water Supply.**

N **9.8.3.3.1** Private hydrants and underground mains, where provided, shall comply with NFPA 24. [**652:**9.8.4.3.1]

N **9.8.3.3.2** Fire pumps, where provided, shall comply with NFPA 20. [**652:**9.8.4.3.2]

N **9.8.3.3.3** Fire protection water tanks, where provided, shall comply with NFPA 22. [**652:**9.8.4.3.3]

N **9.8.4 Spark/Ember Detection and Extinguishing Systems.** Where provided, spark/ember detection and extinguishing systems shall be designed, installed, and maintained in accordance with NFPA 15, NFPA 69, and *NFPA 72*. [**652:**9.8.6]

N **9.8.5 Special Fire Protection Systems.**

N **9.8.5.1** Automatic extinguishing systems or special hazard extinguishing systems, where provided, shall be designed, installed, and maintained in accordance with the following standards, as applicable:

(1) NFPA 11
(2) NFPA 12
(3) NFPA 12A
(4) NFPA 15
(5) NFPA 16
(6) NFPA 17
(7) NFPA 25
(8) NFPA 750
(9) NFPA 2001
[**652:**9.8.7.1]

N **9.8.5.2** The extinguishing systems shall be designed and used in a manner that minimizes the generation of dust clouds during their discharge. [**652:**9.8.7.2]

Chapter 10 Fire Prevention, Fire Protection, and Emergency Response

10.1 Retroactivity. The requirements of this chapter shall apply retroactively.

N **10.2 General.** The procedures and training in this chapter shall be delivered in a language that the participants can understand. [**652:**8.2]

N **10.2.1** Documentation shall be maintained in compliance with Section 8.13.

N **10.3 Operating Procedures and Practices.**

N **10.3.1*** The owner/operator shall establish written procedures for operating its facility and equipment to prevent or mitigate fires, deflagrations, and explosions from combustible particulate solids. [**652:**8.3.1]

N **10.3.2*** The owner/operator shall establish safe work practices to address hazards associated with maintenance and servicing operations. [**652:**8.3.2]

N **10.3.2.1** The safe work practices shall apply to employees and contractors. [**652:**8.3.2.1]

10.4 Fire Prevention.

10.4.1 Inspection, Testing, and Maintenance.

10.4.1.1 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.

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

(1) Fire and explosion protection and prevention equipment in accordance with the applicable NFPA codes and standards
(2) Dust control equipment
(3) Housekeeping
(4) Potential ignition sources
(5) Electrical, process, and mechanical equipment, including process interlocks
(6) Process changes
(7) Continuity check on grounding and bonding systems
(8) Resistivity testing of static-dissipative footwear and conductive floors where required
(9) Piping systems that carry or transport combustible/flammable 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).

N **10.4.1.3** The owner/operator shall establish procedures and schedules for maintaining safe operating conditions for its facility and equipment in regard to the prevention, control, and mitigation of combustible dust fires and explosions. [**652:**8.7.3]

10.4.1.4 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.

10.4.1.4.1 The inspection shall be conducted at least quarterly.

10.4.1.4.2 The inspection and testing shall be conducted by a person(s) knowledgeable in the proper practices who shall document the findings and recommendations.

N **10.4.1.4.3*** Where equipment deficiencies that affect the prevention, control, and mitigation of dust fires, deflagrations, and explosions are identified or become known, the owner/operator shall establish and implement a corrective action plan with an explicit deadline. [**652:**8.7.4]

10.4.1.5 Operating and maintenance procedures shall be reviewed annually and as required by process changes.

N **10.4.1.6** Document retention shall be in compliance with Section 8.13.

10.4.2 Control of Combustible Materials.

10.4.2.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

10.4.2.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

10.4.2.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

10.4.2.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

10.4.2.2 Ordinary Combustible Storage.

10.4.2.2.1 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.

10.4.2.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

10.4.2.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

10.4.2.3.1 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.

10.4.2.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitible shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

10.4.3* Molten Metal.

10.4.3.1 All containers used to receive molten metal, molten titanium, molten titanium chloride, or liquid alkali metals shall be cleaned and dried thoroughly before use.

10.4.3.2 All pieces of metal shall be clean and dry when charged to reactors.

10.5 Fire Protection.

10.5.1 Automatic Sprinkler Protection for Combustible Metals Other Than Alkali Metals.

10.5.1.1* Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled unless allowed by 10.5.1.2, 10.5.1.3, and 10.5.1.4.

10.5.1.2* 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 jurisdiction knowledgeable of the hazards associated with combustible metals.

10.5.1.3 The hazards analysis shall consider the possibility of fires and explosions involving both combustible metals and the other combustibles.

10.5.1.4 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.

10.5.1.5 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 10.5.4.

10.5.1.6* Light casting storage areas shall be protected by automatic sprinklers in any of the following situations:

(1) Where storage in quantities greater than 28 m^3 (989 ft^3) 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 9 m (30 ft) of the magnesium

10.5.2 Sprinkler Protection for Alkali Metals.

10.5.2.1* 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.

10.5.2.2 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.

10.5.2.3 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.

10.5.2.4 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.

10.5.2.5 Fire-extinguishing agents compatible for the hazards present shall be readily available in combustible metals-scrap storage areas.

10.5.2.6* Fire-extinguishing agents compatible for the hazards present shall be readily available in combustible-metals-powder storage areas.

10.5.3* Extinguishing Agents and Application Techniques.

10.5.3.1* 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.

10.5.3.1.1 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.

10.5.3.1.2 Any agent that when applied at the recommended rate results in an increase in fire intensity shall be prohibited.

10.5.3.2 A supply of extinguishing agent for manual application shall be kept within easy reach of personnel working with combustible metal powder.

10.5.3.3 Container lids shall be kept in place to prevent agent contamination and to keep agents moisture free.

10.5.3.4 Portable or wheeled extinguishers listed for use on combustible-metal fires shall be provided and shall be distributed in accordance with NFPA 10.

10.5.3.5 The following agents shall not be used as extinguishing agents on a combustible-metal fires because of adverse reactions or ineffectiveness unless they are compatible with the metal and are an effective extinguishing agent *(see 10.5.3)*:

(1) Water
(2) Foams
(3) Halon
(4) Carbon dioxide
(5)* Nitrogen (IG-100)
(6) Halocarbon Clean Agents

10.5.3.6 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.

10.5.3.7 Fire-extinguishing agent expellant gases shall be compatible with the combustible metal.

10.5.3.8 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."

10.5.3.9* Solvent-Wetted Powders. Incipient fires in solvent-wetted powders shall be handled according to 10.5.3.9.1 or 10.5.3.9.2.

10.5.3.9.1 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.

10.5.3.9.2 An incipient fire occurring in semi-wet material or filter cake shall be fought using a listed Class B extinguishing agent.

10.5.3.9.2.1* 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.

10.5.3.9.2.2* 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.

10.5.3.9.2.3 The material shall be handled in covered containers.

10.5.3.10 Applications of Extinguishing Agents. Applications of extinguishing agents shall be handled according to 10.5.3.10.1 through 10.5.3.10.4.

10.5.3.10.1* 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.

10.5.3.10.2 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.

10.5.3.10.3* 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.

10.5.3.10.4 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.

10.5.3.11 Fire-extinguishing agents compatible for the hazards present shall be available in metal-scrap storage areas.

10.5.3.12 Fire-extinguishing agents compatible for the hazards present shall be available in metal-powder storage areas.

10.5.4 Fire-Fighting Activities.

10.5.4.1* Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent.

10.5.4.2 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.

10.5.4.3 Combustible-metal fires beyond the incipient stage shall be fought by professional fire fighters, specially trained fire brigade personnel, or both.

10.5.4.4 Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residue has cooled to room temperature.

10.5.4.5 Fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

10.5.4.6 Fire residues shall be disposed of in accordance with federal, state, and local regulations.

10.5.4.7 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.

10.5.4.8 Processing Equipment.

10.5.4.8.1* When a fire occurs in processing equipment, material feed to the equipment shall be stopped.

10.5.4.8.2 The equipment shall be kept in operation, unless continued operation will spread the fire.

10.5.4.9 Alkali Metals Fire-Fighting Procedures.

10.5.4.9.1* While an alkali-metal fire is being fought, every effort shall be made to avoid splattering the burning alkali metals.

10.5.4.9.2* Once the fire is extinguished and a crust is formed, the crust shall not be disturbed until the residues have cooled to room temperature.

10.5.5 Fire-Fighting Organization.

10.5.5.1 Only trained personnel shall be permitted to engage in fire control activity.

10.5.5.1.1 Personnel other than trained personnel shall be evacuated from the area.

10.5.5.1.2 Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

10.5.5.2 Fire-fighting personnel shall be given training in the extinguishment of test fires set in a safe location away from manufacturing buildings.

10.5.5.2.1 Training shall include all possible contingencies.

10.5.5.2.2* If professional or volunteer fire fighters 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.

N **10.6 Training and Hazard Awareness.**

N **10.6.1*** 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. [**652:**8.8.1]

N **10.6.1.1** Contractors shall also meet the requirements of Section 8.9.

N **10.6.2*** General safety training and hazard awareness training for combustible metal fire hazards shall be provided to all affected employees.

N **10.6.2.1*** 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.

N **10.6.2.2** Employees shall be trained before taking responsibility for a task. [**652:**8.8.2.2]

N **10.6.2.3*** 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.

10.6.3* 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.

N **10.6.4** Personnel assigned to fire control activities shall be trained in accordance with 10.5.5.

N **10.6.5** Refresher training shall be provided as required by the AHJ and as required by other relevant industry- or commodity-specific NFPA standards. [**652:**8.8.3]

N **10.6.6** The training shall be documented. [**652:**8.8.4]

10.7 Emergency Planning/Preparedness and Response.

10.7.1 Local emergency response agency notification shall be required for any operation storing or processing 2.27 kg (5 lb) or more of powder, dusts, fines, or alkali metal in any form or 227 kg (500 lb) or more of chips or turnings.

10.7.2* 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.

N **10.7.2.1*** The plan shall be developed to prepare for and respond to work-related emergencies including, but not limited to, fire and explosion.

10.7.2.2 This plan shall be available on site to emergency responders.

N **10.7.2.3** The emergency response plan shall be reviewed and validated at least annually, highlighting specific actions in the event of a combustible metal fire.

Δ **10.7.2.4** The plan shall be coordinated with the facility management and emergency responders.

10.7.2.5* Clothing Fires.

10.7.2.5.1 Emergency procedures for handling clothing fires shall be established as part of the plan.

10.7.2.5.2 If deluge showers are installed, they shall be located away from dry metal powder–processing and metal powder–handling areas.

10.7.2.6 The plan shall address locations for remote shutoff 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) Flammable liquids
(5) Toxic materials
(6) Other hazardous materials

10.7.2.7 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 10.5.3.)*
(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 flammable or combustible liquids are used and the metal is not yet involved in the fire. *(See 10.5.3.)*
(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 3857°C (7000°F) and 4690°C (8500°F), 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 20°C (68°F). 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 10.5.3.)*
(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.

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10.7.3 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.

10.7.4 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.

10.8* Emergency Response.

10.8.1 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 10.5.3.)*
(12) Use extinguishing agents for containment of small and incipient fires. *(See 10.5.3.)*
(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.

N **10.9 Incident Investigation.** Incident investigation shall comply with Section 8.11.

Chapter 11 Housekeeping

11.1 Retroactivity. The requirements this chapter shall apply to new and existing facilities.

11.2 Applicability. The requirements of this chapter shall not apply to nanometals *(see Chapter 14)*.

11.3* Housekeeping Plan.

11.3.1 A documented housekeeping program shall be established.

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

11.3.3* Procedures for unscheduled housekeeping of unplanned or accidental spillage of combustible metal dusts in operating areas shall be established as a part of a housekeeping plan.

11.4 Cleanup Procedures for Fugitive Dust Accumulations.

11.4.1* Fugitive dust shall not be allowed to accumulate to a level that obscures the color of the surface beneath it.

11.4.2* 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.

11.4.3 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 Section 11.6

11.4.4 Special attention shall be paid to areas utilizing powder for accumulations in crevices and joints between walls, ceilings, and floors.

11.4.5 Systematic cleaning of areas containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as frequently as conditions warrant.

11.4.5.1 The cleaning shall include machinery.

11.4.5.2 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.

11.4.5.3 Chips or powder sweepings shall be removed to a designated storage or disposal area.

11.4.5.4 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.

11.4.5.5 Collected dust and fines shall be removed to a safe storage or disposal area.

11.5 Cleanup of Spilled Dust, Fine or Powder.

11.5.1 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.

11.5.2 Vacuum cleaners shall be permitted to be used only for residual amounts of material remaining after preliminary cleanup.

11.5.3 Compressed-air blowdown shall be permitted as a method for cleaning only when done in accordance with Section 11.7.

11.6* Vacuum Cleaning.

11.6.1 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.

Δ **11.6.2*** 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

11.6.3* Vacuum cleaning systems shall be effectively bonded and grounded during use to minimize the accumulation of static electric charge.

11.6.3.1* If the system is moved, grounding and bonding shall be verified.

N **11.6.3.2** For compressed air-operated systems, the air supply hose shall comply with the manufacturer's specifications.

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11.6.4 Vacuum cleaner hose shall be conductive or static dissipative and nozzles or fittings shall be made of conductive, nonsparking material.

11.6.5 Assembled components shall be conductive or static dissipative and bonded where necessary.

11.6.6* When a vacuum cleaner is used for other materials, the equipment shall be thoroughly cleaned prior to its use and identified accordingly.

Δ **11.6.7** Combustible metal dust picked up by a centralized vacuum cleaning system shall be discharged into a container located outside the building.

11.6.8 Sludge from dust collectors and vacuum cleaning system precipitators shall be removed weekly, as a minimum, and when equipment is shut down after use.

11.7 Compressed Air Cleaning Requirements.

11.7.1 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.

Δ **11.7.1.1** Vigorous sweeping or blowing down with compressed air produces dust clouds and shall be permitted only where the following requirements are met:

(1) 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.
(2) Compressed air shall not exceed a gauge pressure of 206 kPa (30 psi) unless otherwise determined to be safe by a documented hazard analysis.

11.7.2 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.

11.8 Water-Cleaning Requirements.

11.8.1 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

11.8.2 Water-cleaning shall not be permitted in areas that have exposed alkali or water reactive materials.

11.8.3 Hose used for cleaning and wash down purposes shall be pressurized only while in active use for cleaning and wash down purposes.

11.9 Cleaning Frequency.

11.9.1* The accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned in daily operations shall be minimized.

11.9.2 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.

11.9.3* The housekeeping frequency shall be established to ensure that the accumulated dust levels on walls, floors, and horizontal surfaces, such as equipment, ducts, pipes, conduits, hoods, ledges, beams, roof members, and above suspended ceilings and other concealed areas, such as the interior of electrical enclosures, does not exceed the threshold accumulation.

11.9.4 Collected fugitive metal dust shall be removed to a designated storage or disposal area.

11.10 General Precautions.

11.10.1 Supplies of production materials in processing areas shall be limited to the amounts necessary for normal operations.

11.10.2 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.

11.10.3 Oil spills shall be cleaned up promptly.

11.10.4 Supplies shall be stored in an orderly manner with properly maintained aisles to allow routine inspection and segregation of incompatible materials.

11.10.5 Except for alkali metals, floor sweepings from combustible-metal-dust operations shall be permitted to contain small amounts of ordinary combustible materials.

11.10.6 The review of the hazards associated with cleaning operations shall include isolation, minimization, and elimination of the hazards.

11.10.7 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.

Chapter 12 Control of Ignition Sources

12.1* Retroactivity. Unless otherwise specified, the requirements of this chapter shall be applied retroactively.

12.2 Hot Work. See Section 8.5.

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12.3 Control of Friction Hazards. All machinery shall be installed and maintained in such a manner that the possibility of friction sparks is minimized.

12.3.1 Bearings.

12.3.1.1 Ball or roller bearings shall be sealed against dust.

12.3.1.2 Where exposed bearings are used, the bearings shall be protected to prevent ingress of combustible metal dust and shall have a lubrication program.

12.3.1.3 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

12.3.1.4 Localized frictional heating of bearings in any machine shall be minimized.

12.3.1.5 Grounded and bonded bearings shall be used.

12.3.1.6 Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes, a conductive lubricant, or other applicable means.

12.3.2 Fan and Blower Construction.

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

12.3.2.2* 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.

12.3.2.3 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.

12.3.2.4* Fans or blowers shall be equipped with ball or roller bearings.

12.3.2.4.1 Bearings shall be equipped with temperature indicating devices.

12.3.2.4.2 Bearings shall be arranged to sound an alarm in case of overheating.

12.3.2.5 Fans and blowers shall be electrically interlocked with powder-producing machinery so that the machines can operate only if the fans are operating.

12.3.3* Grinding Wheels.

12.3.3.1 Wheels used for grinding combustible metal castings shall be relocated for dressing.

12.3.3.2 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.

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12.4 Electrical Area Classification.

12.4.1* The identification of the possible presence and extent of combustible dust hazardous (classified) locations shall be made based on the criteria in Article 500 or 506 of *NFPA 70*.

12.4.2 All areas designated as hazardous (classified) locations shall be documented, and such documentation shall be maintained and preserved for access at the facility.

12.4.3 Electrical equipment and wiring within combustible dust locations shall comply with *NFPA 70*.

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

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N **12.5* Portable Electrical and Electronic Equipment.** Portable electrical and electronic equipment used in hazardous (classified) locations shall be identified for use in such locations. *(See NFPA 70.)*

Δ Chapter 13 Pneumatic Conveying, Dust Collection, and Centralized Vacuum Cleaning Systems

13.1 Retroactivity. Paragraphs 13.2.4.2.2, 13.2.4.4.6, 13.2.4.4.12, 13.2.4.4.15.3, 13.2.4.5.9, and Section 13.4 shall be applied retroactively.

13.2* Dust Collection.

13.2.1* 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 this chapter.

13.2.2 Powder conveying and collection for combustible metal powder production operations shall follow the requirements of Section 13.5, 13.2.4.4, and 13.2.4.5 for wet and dry AMS.

13.2.3 General Requirements.

13.2.3.1 All dust collection systems shall be installed in accordance with NFPA 91.

13.2.3.2* 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. [**652:**8.3.3.1.1]

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

13.2.3.4* The dust collection 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.

13.2.3.5 Restrictions on Collected Materials.

13.2.3.5.1 Dust collection systems shall not be used to collect incompatible materials or other materials that might react with the conveyed metal dusts or particles.

13.2.3.5.1.1 The collection of any metal other than the metal the system was designed to collect shall be prohibited.

13.2.3.5.1.2 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 this chapter are maintained.

13.2.3.6 Operations.

13.2.3.6.1 Sequence of Operation. Dust collection systems shall be designed with the operating logic, sequencing, and timing outlined in 13.2.3.6.1.1 and 13.2.3.6.1.2.

13.2.3.6.1.1 Startup. Dust collection systems shall be designed such that, on startup, the system achieves and maintains design air velocity prior to the admission of material into the system.

13.2.3.6.1.2 Shutdown.

(A) Dust collection systems shall be designed such that, on normal shutdown, the system maintains design air velocity until material is purged from the ducting.

(B) The requirements of 13.2.3.6.1.2(A) shall not apply during emergency shutdown of the system, such as by activation of an emergency stop button or by activation of an automatic safety interlocking device.

13.2.3.6.2* At each collection point, the system shall be designed to achieve the minimum velocity required for capture, control, and containment of the dust source. [**652:**8.3.3.3.1]

13.2.3.6.3* The hood or pickup point for each dust source shall have a documented minimum air volume flow based upon the system design. [**652:**8.3.3.3.2]

13.2.3.6.4* 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. [**652:**8.3.3.3.3]

13.2.3.6.5* 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. [**652:**8.3.3.3.4]

13.2.3.6.6* All dust sources (i.e., hoods) shall be connected using only a tapered main design.

13.2.3.6.7* 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 9.7.3.3, NFPA 68, and NFPA 69.

13.2.3.6.8* The air-material separator (AMS) selected for the system shall be designed to allow for the characteristics of the combustible dust being separated from the air or gas flow. [**652:**8.3.3.3.6]

13.2.3.6.9* 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.

13.2.3.6.10* All dust collection systems for combustible metal dusts shall have the AMD located on the clean side of the AMS.

13.2.3.6.11* 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.

13.2.3.6.12* 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.

13.2.3.7* 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.

13.2.3.7.1 The data plate on the dry-type AMS 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

13.2.4 Specific Requirements.

13.2.4.1* A means shall be provided to prevent condensation in the ductwork.

13.2.4.2* Prevention of Static Discharge.

13.2.4.2.1 Prevention of ignition due to static discharge shall be in accordance with subsection 9.4.7.1 in addition to the requirements of this chapter.

13.2.4.2.2 Bonding and Grounding.

13.2.4.2.2.1* All components of dust collection systems shall be bonded and grounded independently of the electrical grounding system to minimize accumulation of static electric charge.

13.2.4.2.2.2 When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

13.2.4.2.2.3* 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.

13.2.4.3 Ducts, Ductwork, and Flex Connections.

13.2.4.3.1 All ducts and ductwork shall be constructed of metal or noncombustible conductive material.

13.2.4.3.2* Ducting runs shall be as short as practical with minimal turns.

13.2.4.3.3* Where the conveying duct is exposed to weather or moisture, it shall be moisture- and weathertight.

13.2.4.3.4* Hose and flexible connection length shall be the minimum required to accomplish the reason for their use.

13.2.4.3.5* All hoses and flex connections shall be conductive, static dissipative, or otherwise properly bonded/grounded to prevent accumulation of electrostatic charges.

13.2.4.3.6 Grinding operations shall not be served by the same dust collection system as buffing and polishing operations.

13.2.4.4* Dry-Type Air-Material Separator (AMS) Requirements.

13.2.4.4.1* 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 dust hazard analysis (DHA) that is acceptable to the AHJ.

Δ **13.2.4.4.2** 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.

13.2.4.4.3* The ingress, accumulation, or condensation of water in a dry-type AMS shall be prevented.

13.2.4.4.4 Dry-Type AMS Limitations.

13.2.4.4.4.1* Electrostatic collectors shall be prohibited.

13.2.4.4.4.2 Enclosureless dry-type AMS shall be prohibited.

Δ **13.2.4.4.4.3*** Self-contained, dry-type AMS, downdraft benches, and environmental control booths with integral filter media in the wall shall be prohibited unless complying with 13.2.4.4.4.4.

Δ **13.2.4.4.4.4*** 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 0.22 kg (0.5 lb) of dust less than 500 microns is contained in the collector at any given time.

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13.2.4.4.5* 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.

13.2.4.4.6 Repairs.

13.2.4.4.6.1 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.

13.2.4.4.6.2 Ductwork leading into the AMS shall be disconnected and blanked off before repair work shall be permitted to be started.

13.2.4.4.7 Cyclone Construction.

13.2.4.4.7.1 Cyclone dry-type AMS shall be of conductive nonsparking construction suitable for the service intended.

13.2.4.4.7.2* Cyclone dry-type AMS shall be constructed with smooth internal seams to minimize material accumulation.

13.2.4.4.8 Temperature Monitoring Requirements.

13.2.4.4.8.1* Dry-type AMS shall be equipped with fire detection and alarm devices.

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13.2.4.4.8.2 The detection device shall interlock and deenergize the system and provide an audible and visual alarm at normally attended stations.

N **13.2.4.4.8.3** Where the AMS contains filter media, detection shall be designed so that all filter locations are monitored.

13.2.4.4.9* 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.

13.2.4.4.10 Filter Media Properties.

13.2.4.4.10.1* Cartridge filters shall not be used with pyrophoric metal dusts.

13.2.4.4.10.2 Filter media shall not be chemically reactive with the collected dust, including any contaminants carried in the dust stream with the combustible metal.

13.2.4.4.11 Explosion Protection.

13.2.4.4.11.1 Where provided, explosion protection shall be directed to a safe location away from areas where personnel are normally present.

Δ **13.2.4.4.11.2*** 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

13.2.4.4.11.3 If the method in 13.2.4.4.11.2(5) is used, test data for specific dust and diluent combinations shall be provided and shall be acceptable to the authority having jurisdiction.

13.2.4.4.11.4 Where an explosion hazard exists and is not protected by 13.2.4.4.11.2(2) or 13.2.4.4.11.2(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.

(A)* Explosion isolation shall be provided in accordance with NFPA 69 between the dust collector and upstream process.

(B) 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.

13.2.4.4.11.5 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.

13.2.4.4.11.6 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

Δ **13.2.4.4.11.7** 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.

Δ **13.2.4.4.11.8** Where collectors are provided with deflagration vents, vent closures shall be clearly marked with, at a minimum, the following text:

WARNING:

EXPLOSION RELIEF DEVICE

13.2.4.4.12 Collected Material.

13.2.4.4.12.1* 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 determined by the DHA.

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13.2.4.4.12.2 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.

13.2.4.4.12.3 Precautions shall be taken to avoid creating dust clouds when removing dust from the collectors.

13.2.4.4.12.4 The dust removed shall be recycled or disposed of in accordance with local, state, and federal regulations.

13.2.4.4.12.5 The dust shall be discharged into metal containers that shall be promptly and tightly covered to avoid the creation of airborne fugitive dust.

13.2.4.4.13* Requirements for the Clean Air Exhaust.

13.2.4.4.13.1 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 2300°C (4172°F).
(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 or 15 mg/m^3, whichever is lower.
(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 DHA 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 DHA 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 Chapter 11.
(10) Recycled-air ducts are inspected and cleaned at least annually.

Δ **13.2.4.4.13.2** Air shall be permitted to be recirculated for materials not meeting items 13.2.4.4.13.1(1) and 13.2.4.4.13.1(2) if the AMS has a collection capacity meeting the requirements of 13.2.4.4.15.8.

13.2.4.4.14 Dry-type dust collectors shall be located outside of buildings unless permitted by 13.2.4.4.15.

13.2.4.4.15* Indoor Dry-Type Air-Material Separator (AMS). All portions of 13.2.4.4 on dry-type AMS requirements shall apply to indoor dry-type AMS in addition to this section.

13.2.4.4.15.1 A hazards analysis shall be conducted in accordance with Section 5.3 and Chapter 7 to ensure that the risk to personnel and operations is minimized for both new and existing systems.

13.2.4.4.15.2 The collector shall be designed to comply with all applicable requirements in this chapter.

13.2.4.4.15.3 The requirements for fire protection for indoor dry-type dust collection systems shall apply retroactively.

(A) 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.

(B) An automatic fixed fire suppression system shall not be required where the amount of material collected is less than 0.45 kg (1 lb) combustible metal and the dust collector is emptied after each day of operation.

(C) 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.

(D) The collection of materials other than iron or steel dust shall be prohibited in collectors with a dirty volume greater than 0.57 m^3 (20 ft^3) or an airflow greater than 2549 m^3/hr (1500 ft^3/min).

(E)* 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.

Δ **13.2.4.4.15.4*** Exhaust ducts from the fan discharge exiting the building shall be as straight and short as is practicable.

13.2.4.4.15.5* The collector inlet duct, exhaust duct, and blower shall be inspected at least every 6 months to ensure that material is not accumulating.

Δ **13.2.4.4.15.6** 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

13.2.4.4.15.7* If the material meets either of the following criteria, the additional requirements in 13.2.4.4.15.7(A), 13.2.4.4.15.7(B), and 13.2.4.4.15.7(C) 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.10.5.3*).

(A)* 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.

Δ **(B)** The collector shall contain a warning sign stating the following:

THIS COLLECTOR CONTAINS COMBUSTIBLE METAL DUST.

DO NOT EXTINGUISH WITH WATER.

(C) The emergency response plan required in Section 10.8 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

Δ **13.2.4.4.15.8** Indoor dry-type dust collectors shall be permitted for legacy metals covered by Chapter 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 4.5 kg (10 lb) of material greater than 500 microns with a maximum of 0.45 kg (1 lb) of material less than 500 microns for an aggregate of 5 kg (11 lb) total.
(2) The AMS has a dirty volume less than 0.2 m^3 (8 ft^3) or an airflow less than 850 m^3/hr (500 ft^3/min), and the discharge container is emptied in accordance with 13.2.4.4.12.

13.2.4.4.15.9 Indoor dry-type dust collectors shall be permitted for metals covered by Chapter 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 0.57 m^3 (20 ft^3) or an airflow greater than 2549 m^3/hr (1500 ft^3/min).

N **13.2.4.4.15.10** Where an entire dust collection and AMS system, including the material collection container, is protected from fire and explosion in accordance with 13.2.4.4.11.2(2), the quantity of collected material shall be permitted to be increased to 227 kg (500 lb), or a value determined by a DHA.

13.2.4.4.16* Portable Indoor Dry-Type Air-Material Separators (AMS) (Dust Collectors).

13.2.4.4.16.1 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 13.2.4.4.16.

13.2.4.4.16.2 Portable indoor dry-type dust collectors shall not be connected to a permanent fixed piping system.

13.2.4.4.16.3 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.

(A)* The portable dust collector shall not be used in an identified deflagration hazard area until appropriate housekeeping methods in Chapter 11 have been used to remove hazardous quantities of dust.

(B)* Portable dry AMS with a dirty side volume less than or equal to 0.2 m^3 (8 ft^3) shall not be required to be protected against explosion in accordance with NFPA 69.

13.2.4.4.16.4 Personal protective clothing shall comply with Section 8.6.

13.2.4.4.16.5 Prior to a change in the collected materials, the portable dry-type AMS and all associated components shall be thoroughly cleaned.

13.2.4.4.16.6 Grounding of personnel operating portable indoor dust collectors shall comply with 9.4.7.1.6.

13.2.4.4.16.7 The AMS and any associated components shall be bonded and grounded to an earth ground.

13.2.4.4.16.8 Hazards associated with static discharge shall be mitigated in accordance with subsection 9.4.7.1.

13.2.4.4.16.9 Hoses shall be appropriate for use and be static dissipative or conductive.

13.2.4.4.16.10* 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.

13.2.4.4.16.11 The resistance of the path to ground shall be documented and maintained.

13.2.4.4.16.12* The material collected shall be limited to 2.2 kg (5 lb) and, at a minimum, emptied daily.

13.2.4.4.16.13 The collector shall not be used on processes generating hot embers or sparks.

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13.2.4.4.17 Operations Generating Hot Particles.

13.2.4.4.17.1* Grinding, sanding, polishing, cutting/sawing, plasma spray, or other operations generating hot metal particles shall have a spark arrester system upstream of the AMS.

13.2.4.4.17.2* Dust collection systems for hot metallic nanoparticles shall be inerted unless combustibility testing of nanoparticle dust samples demonstrate that the particles are not pyrophoric.

13.2.4.4.17.3* Ordinary combustibles shall not be allowed to enter dust collection systems using dry-type AMS collecting hot metal particles.

13.2.4.4.17.4 Metal temperatures at the dust collector shall be compatible with the limiting temperature of the filter media.

13.2.4.5* Wet-Type Air-Material Separator (AMS) Requirements.

13.2.4.5.1 The exhaust vent shall terminate to a safe location outside the building and shall be securely fastened except as provided in 13.2.4.5.3.

13.2.4.5.2 The clean air shall not be permitted to be returned to an identified deflagration hazard area.

13.2.4.5.3 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.

13.2.4.5.4 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.

13.2.4.5.5* 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.

13.2.4.5.6* The wet-type AMS shall meet or exceed the design efficiency of combustible dust collection at all times during normal operation.

13.2.4.5.7 The use of additional dry filter media either downstream or combined with a wet collector shall not be permitted.

13.2.4.5.7.1 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

13.2.4.5.8 Operational Safeguards.

13.2.4.5.8.1* 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.

13.2.4.5.8.2 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.

13.2.4.5.8.3 An interlock shall be provided to prevent operation of the wet-type AMS unless water tank capacity and water supply is maintained.

13.2.4.5.8.4 The AMS shall be constructed of conductive materials or be static dissipative.

13.2.4.5.9* Disposal of Sludge from Water-Based Wet-Type Air-Material Separators.

13.2.4.5.9.1* 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.

13.2.4.5.9.2 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.

13.2.4.5.9.3 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.

13.2.4.5.9.4 Smoking or open flames shall be prohibited in the disposal area and throughout the disposal process.

13.2.4.5.9.5 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.

13.2.4.5.9.6 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.

13.2.4.5.10* Requirements to Prevent the Buildup of Hydrogen in Water-Based Wet-Type Air-Material Separators.

13.2.4.5.10.1 Wet-type AMS shall be designed so that hydrogen generated from the metal contacting the water is vented at all times.

13.2.4.5.10.2 Vents shall remain open and unobstructed when the machine is shut down.

13.2.4.5.10.3 When the AMS is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

13.2.4.5.10.4 Each chamber of the AMS shall be vented to dissipate the hydrogen.

13.2.4.5.10.5 Sludge shall be removed from the AMS whenever the AMS is to remain inoperative for a period of 24 hours or more.

13.2.4.5.11 Additional Requirements for Water-Based Wet-Type AMS.

13.2.4.5.11.1 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.

13.2.4.5.11.2 Hydrogen vents shall remain open and unobstructed when the machine is shut down.

13.2.4.5.11.3 When the dust collector is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

13.2.4.5.11.4 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.

13.2.4.5.11.5 Each chamber of the collector shall be vented to dissipate the hydrogen.

13.2.4.5.12 Additional Requirements for Non-Water-Based Wet-Type AMS.

13.2.4.5.12.1 The liquid used shall be limited to nonaqueous Class IIIB or noncombustible liquids.

13.2.4.5.12.2 Possible vapor generation due to metal reaction with the liquid shall be evaluated and addressed as part of the DHA required in Chapter 7.

13.2.4.5.12.3 Class IIIB liquids shall be handled in accordance with NFPA 30.

13.2.4.5.12.4 Pressurized transfer of liquid shall be prohibited.

13.2.4.5.12.5 Formation of liquid residue in the vicinity of the operating unit shall be minimized.

13.2.4.5.13 Portable Indoor Wet-Type Immersion Air-Material Separators (AMS).

13.2.4.5.13.1 Portable indoor wet-type immersion AMS shall comply with 13.2.3.5 and 13.2.4.5.10.1 through 13.2.4.5.10.5, in addition to this section.

13.2.4.5.13.2 Personal protective clothing shall comply with Section 8.6.

13.2.4.5.13.3 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.

13.2.4.5.13.4 Hoses shall be appropriate for use and be static dissipative or conductive.

13.2.4.5.13.5 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.

13.2.4.5.13.6 The maximum capacity shall not exceed 20 lb (9 kg) of sludge.

13.3* Centralized Vacuum Cleaning System.

13.3.1 General Requirements.

13.3.1.1* Where used to handle combustible metal dusts, the system shall be designed by and installed under the supervision of qualified persons who are knowledgeable about this type of system and the associated hazards.

13.3.1.2* Where it is necessary to make changes to an existing system, all changes shall be managed in accordance with the management of change (MOC) policy.

13.3.1.3* 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.

13.3.2* Specific Requirements for Centralized Vacuum Cleaning Systems.

13.3.2.1* 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.

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

13.3.2.3* Vacuum cleaning tools shall be constructed of metal or shall be static dissipative and provide proper grounding and bonding to the hose.

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

13.3.2.5 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.

13.3.2.6* The entire centralized vacuum cleaning system shall be effectively bonded and grounded to minimize the accumulation of static electrical charge.

13.3.2.7* The tubing, piping, or both used in the system shall be metal and properly grounded and bonded.

13.3.2.8* The dry or wet AMS used in the system must comply with the requirements for dust collectors found in 13.2.4.4 for dry-type AMS and 13.2.4.5 for wet-type AMS.

13.3.2.9* 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.

13.4 Portable Vacuum Cleaners.

13.4.1 The use of portable vacuum cleaners shall comply with Section 11.6.

N **13.4.2*** 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 Section 13.3.)*

N **13.4.3** Portable vacuum cleaning systems shall be effectively bonded and grounded to minimize the accumulation of static electric charge.

N **13.4.4** Vacuum cleaner hose shall be conductive or static dissipative and nozzles or fittings shall be made of conductive, nonsparking material.

N **13.4.5** Assembled components shall be conductive or static dissipative and bonded where necessary.

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13.5 Pneumatic Conveying of Powder.

13.5.1 Ductwork for Pneumatic Conveying Systems.

13.5.1.1 Conveyor ducts shall be fabricated of spark-resistant metals that are compatible with the metal being transported.

13.5.1.2 Plastics or other nonconductive ducts or duct liners shall not be used.

13.5.1.3* Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge.

13.5.1.4* Where the conveying duct is exposed to weather or moisture, it shall be moisture-tight.

13.5.1.5* 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 can drop out during unscheduled system stoppages.

13.5.1.6* Where a deflagration hazard exists, deflagration protection such as rupture diaphragms shall be provided on ductwork.

13.5.1.6.1 Deflagration vents shall relieve to a safe location outside the building.

13.5.1.6.1.1 Where provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

13.5.1.6.1.2 It shall be permissible to determine the deflagration vent discharge area using NFPA 68.

Δ **13.5.1.6.1.3** Where ducts are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING:

EXPLOSION RELIEF DEVICE

13.5.1.6.2 Deflagration venting shall not be required for ductwork provided with explosion isolation systems identified in NFPA 69 that can prevent propagation of a deflagration into other parts of the process.

13.5.1.7 Whenever damage to other property or injury to personnel can result from the rupture of the ductwork, or where deflagration relief vents cannot provide sufficient pressure relief, the ductwork shall be designed in accordance with Chapter 13 of NFPA 69.

13.5.1.8 If a portion of the ductwork is located so that no damage to property or injury to personnel will result from its bursting, that portion shall be permitted to be of lightweight construction to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

13.5.2 Conveying Using an Inert Medium.

13.5.2.1* Inert gas–conveying systems shall be permitted if designed in accordance with NFPA 69.

13.5.2.2 The inert gas used shall not react with the specific metal.

13.5.2.3* 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.

13.5.2.4* 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.

13.5.2.5 The oxygen concentration of the inert gas stream shall be monitored in accordance with NFPA 69.

13.5.2.6* The inert gas shall have a dew point so that no free moisture can condense or accumulate at any point in the system.

13.5.2.7* 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.

13.5.2.8* 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.

13.5.3 Fan and Blower Construction and Arrangement.

13.5.3.1 Fans and blowers shall be in accordance with 12.3.2.

13.5.3.2 Personnel shall not be permitted within 15 m (50 ft) of the fan or blower while it is operating, except under either of the following conditions:

(1) If personnel approach the fan or blower to perform a pressure test while the fan is operating, the test shall be done under the direct supervision of competent technical personnel, with the knowledge and approval of operating management, and with the flow of combustible metal powder cut off.
(2) Where the combustible metal powder–conveying system is inerted, personnel shall be permitted to be closer than 15 m (50 ft).

13.5.3.3 No maintenance shall be performed on the fan until it is shut down.

13.5.3.4* Fans or blowers shall be located outside of all manufacturing buildings and shall be located to minimize entrance of dust into the building from the fan exhaust.

13.6 Powder Collection.

13.6.1* Collectors.

13.6.1.1 Dry-type collectors shall be located outside in a safe location and shall be provided with barriers or other means of protection for personnel.

Δ **13.6.1.2*** The area around the collector shall be posted with a sign that reads as follows:

CAUTION:

THIS COLLECTOR CAN CONTAIN EXPLOSIBLE DUST. KEEP OUTSIDE THE MARKED AREA WHILE EQUIPMENT IS OPERATING.

13.6.1.2.1 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

13.6.1.2.2 It shall be permissible to determine the deflagration vent discharge area using NFPA 68.

Δ **13.6.1.2.3** Where collectors are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING:

EXPLOSION RELIEF DEVICE

Δ **13.6.1.3*** Collector enclosures shall be constructed of metal.

13.6.1.4 Ductwork shall comply with the provisions of 13.5.1.

13.6.1.5* The entire collection system, including the collector, shall be completely bonded and grounded to minimize accumulation of static electric charge.

13.6.1.6 Recycling of air from powder collectors into buildings shall be prohibited.

13.6.1.7* Where an explosion hazard exists, dry-type collectors shall be provided with deflagration vents.

13.6.1.7.1 Extreme care shall be taken in the selection of the type and location of vents or weak sections of the collector to minimize injury to personnel and blast damage to nearby equipment or structures.

13.6.1.7.2 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

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13.6.1.7.3 Deflagration vents shall be positioned so that a potential blast is not directed toward any combustible or frangible structure.

Δ **13.6.1.7.4** Vent closures shall be clearly marked as follows:

WARNING:

EXPLOSION RELIEF DEVICE

13.6.2 Repairs.

13.6.2.1 Where repairs on dry-type collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed.

13.6.2.2* Ductwork leading into the collector shall be disconnected and isolated by blanking before repair work is permitted to be started.

13.6.3 High-Temperature Warning.

13.6.3.1 Cyclone or other dry-type collectors shall be equipped with instruments for recording the surface temperature.

13.6.3.2 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 50°C (90°F) below the ignition temperature of the powder cloud, whichever is lower.

13.6.3.3 The devices specified in 13.6.3.2 shall give audible and visual alarms at normally attended locations.

13.6.4* Collector Filter Media. Collector filter media made from synthetic fabrics that accumulate static electric charges shall not be used.

Chapter 14 Nanometal Powders

14.1 Retroactivity. The requirements of this chapter shall apply retroactively.

14.2* General.

14.2.1 Processing, handling, and storage of nanometal powders shall follow the requirements of this chapter in addition to the fire and explosion prevention and mitigation requirements in Chapters 10 through 18.

14.2.2* The requirements of this chapter 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.

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 this chapter do not apply.

14.2.4* Due to the special hazards of nanometals, a DHA conducted in accordance with Chapter 7 shall include a determination of the appropriate effective fire and explosion protection measures for combustible metal nanoparticle processes and equipment.

14.3 Nanoparticle Production Processes.

14.3.1 Nanometal Production Using Exploding Electrical Wires.

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.

14.3.1.2* Fire and explosion protection measures for this process equipment shall be established based on the hazard analysis, other pertinent requirements of this standard, and blast wave protection for the exploding wires.

14.3.1.3 The power supply and electrical circuits used for exploding electrical wire production shall be in accordance with *NFPA 70*.

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.

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.

14.3.2 Nanometal Production with Plasma-Based Processes.

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.

14.3.2.1.1 Fire and explosion protection measures for this process shall be established based on the hazard analysis and the other pertinent requirements of this standard.

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.

14.3.2.3 Particulate cooling, capture, and encapsulation equipment shall be operated per requirements in Section 14.4.

14.3.3 Nanometal Synthesis by Chemical Reduction of Salt Solutions and Colloidal Dispersions.

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.

14.3.3.2 Fire and explosion protection measures for this process shall be established based on the hazard analysis and the other pertinent requirements of this standard.

14.3.3.3* Fire protection for solutions with flammable or combustible liquid solvents shall be in accordance with requirements of NFPA 30.

14.3.4 Biochemical Production of Nanometals.

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.

14.3.4.1.1 Fire and explosion protection measures for this process shall be established based on the hazard analysis and the other pertinent requirements of this standard.

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.

14.4 Equipment Design and Operation.

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.

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.

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.

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.

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.

14.5 Housekeeping.

14.5.1* A documented housekeeping program shall be established based on the hazards described in the DHA for all nanometal particles and shall include special provisions for preventing personnel exposure to nanoparticles during cleaning.

14.5.1.1 The location and extent of potential nanoparticle deposits shall be described in the program documentation.

14.5.1.2 The likelihood of ignition during cleaning shall also be documented.

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.

Chapter 15 Additive Manufacturing

15.1 Retroactivity. The requirements of this chapter shall apply retroactively.

15.2* General Requirements.

Δ **15.2.1*** A dust hazards analysis (DHA) conducted per Chapter 7 shall include the additive manufacturing process equipment and materials.

15.2.2 Additive manufacturing facility construction and layout, including powder storage provisions, shall meet the requirements of Chapters 16 through 18 for all applicable metals in addition to the requirements of this chapter.

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15.2.3* Provisions for Emergency Shutdown for Systems Containing More than 22.7 kg (50 lb).

15.2.3.1 The control system shall automatically shut down on any of the following conditions:

(1) Loss of purge gas
(2) High chamber temperature 50°C (90°F) above normal operating temperature
(3) Loss of vacuum

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15.2.3.2* The additive manufacturing equipment shall be provided with a local and a remote manual emergency shutdown device.

N **15.2.3.2.1** For existing installations, the DHA shall determine whether a remote manual emergency shutdown device is required.

N **15.2.3.2.2** All new installations shall be provided with a remote manual emergency shutdown device.

N **15.2.3.2.3** Where the automatic shutdown system required by 15.2.3.1 is installed as an explosion protection system in accordance with NFPA 69, the remote manual emergency shutdown device shall not be required.

N **15.2.3.2.4** 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.

15.2.3.2.5 Shutdown shall deactivate the affected printing operations without creating additional hazards.

15.2.3.2.6 Shutdown shall not deactivate the purge gas or the vacuum system of the affected system.

15.2.4 Shipping and Handling Containers.

15.2.4.1* 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.

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15.3 Additive Manufacturing Equipment and Operations.

15.3.1 General.

15.3.1.1 All pieces of fixed equipment shall be grounded and bonded in accordance with NFPA 77.

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.

N **15.3.1.3*** Control measures shall be employed to minimize the formation of suspended dust clouds during transfer of powder.

N **15.3.1.4*** Where equipment operation requires manual removal of the part, the equipment in proximity to the part removal location, as determined by the DHA, shall be designed for installation in a Class II, Division 1, Group E location.

N **15.3.1.5** Portable vacuum cleaners used in additive manufacturing operations shall comply with the requirements in Section 13.4.

N **15.3.2* Storage of Powders.**

N **15.3.2.1** The quantity of powder in the staging area and in the AM production area shall be determined by the DHA.

N **15.3.2.2** DHA determination of the allowable quantity of powder shall address:

(1) The applicable MAQs (i.e., flammable solid)
(2) The number of storage containers
(3) The types of containers
(4) The degree of hazard associated with handling the containers

N 15.3.2.3 The DHA shall determine the requirements for how the container is stored in the AM production facility.

N 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 9.4.7.4 and Sections 16.8, 17.8, and 18.8.

N 15.3.2.5 The DHA shall address the storage of recovered powders and waste powders.

15.3.3 Powder Weighing Operations.

Δ **15.3.3.1*** Powder weighing equipment shall be grounded.

15.3.3.2* Open conductive powder containers shall be bonded before weighing the container.

15.3.3.3 All containers or hoppers used for intermediate handling of powders shall be conductive or static dissipative.

15.3.3.4 Where the requirement of 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.

N **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.

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15.3.4 Sieving Operations.

15.3.4.1 Powder sieving equipment shall be bonded and grounded.

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.

15.3.4.3 Portions of sieving equipment that come in contact with powders shall be conductive or static dissipative.

15.3.4.4 Where the requirement of 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.

N **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.

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15.3.5* Powder Transfer Equipment.

15.3.5.1 Bonding and grounding connections shall be verified prior to the transfer of powder.

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15.3.5.2 Containers used to transfer powder shall be designed to minimize spillage.

N **15.3.5.2.1** Powder containers shall be safely transported to avoid powder spills and dust cloud formation.

N **15.3.5.2.2** Transport containers shall be adequately closed and secured to the transport cart.

N **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 standard.

N **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 standard.

15.3.6 3D Printing.

15.3.6.1 Startup.

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.

N **15.3.6.1.2** The LOC shall be determined for the inert gas being used per the NFPA 69 requirements.

15.3.6.1.3 Inerting operations shall be in accordance with 13.5.2.2 through 13.5.2.8, and the inert gas supply shall be monitored per NFPA 69.

Δ **15.3.6.1.4*** 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.

15.3.6.1.5 Purged enclosures shall be in accordance with NFPA 496.

15.3.6.2 Powder Bed Printing.

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.

N **15.3.6.2.2** The LOC shall be determined for the inert gas being used per NFPA 69 requirements.

15.3.6.2.3 The inert gas supply shall be monitored per NFPA 69.

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15.3.6.2.4 Powder shall be transported from the bed to the build platform without forming dust clouds.

15.3.6.2.5* 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.

15.3.6.2.5.1 In addition to the requirements in NFPA 69, inerting operations shall be in accordance with 13.5.2.2 through 13.5.2.8 of this standard.

15.3.6.3* Powder Spray Printing.

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.

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.

15.3.6.3.3 The inert gas supply shall be monitored per NFPA 69.

15.3.6.3.4 The powder spray equipment and operations shall be in accordance with the applicable provisions of NFPA 33.

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.

15.3.6.3.5.1 In addition to the requirements in NFPA 69, inerting operations shall be in accordance with 13.5.2.2 through 13.5.2.8 of this standard.

N **15.3.6.4* Other AM Processes. (Reserved)**

15.3.6.5 Object Harvesting.

15.3.6.5.1* Printed object removal shall be performed to minimize the potential for formation of a dust cloud.

N **15.3.6.5.2** Compressed air shall not be used for the removal of loose powder from printed objects during any harvesting operation.

N **15.3.6.5.3*** Internal and external vacuum sources and hoses used for the removal of loose powder from printed objects shall be approved for use with powders.

N **15.3.6.5.4** Hoses for fixed or portable vacuum systems shall be conductive or static dissipative.

N **15.3.6.5.5** The harvested object shall be transported from the printer in a container that prevents the dispersal of dust from the object into the surrounding area.

N **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.

N **15.3.6.5.7** Other means of removal, determined by the DHA, shall be permitted provided that a level of protection equivalent to the inerting of the build chamber is utilized.

N **15.3.6.5.8** The DHA shall address personnel hazards associated with venting of inert gas when opening the printer cabinet.

15.3.6.6* Post-Processing Operation.

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.

N **15.3.6.6.2** The remaining powder shall be removed while minimizing the potential for dust clouds and ignition sources *(see Section 15.4)*.

N **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.

15.3.6.6.4 Powder and dust generated during post processing shall be captured or conveyed in accordance with Chapter 13.

15.3.6.7 Fire Protection Systems.

15.3.6.7.1 Fire protection systems shall be in accordance with Chapter 10.

15.4 Equipment and Object Cleaning.

Δ **15.4.1*** Equipment for cleaning shall be approved for use with the combustible powder being cleaned.

15.4.2 Equipment used for cleaning, including grounding and bonding, shall be in accordance with the requirements of Chapter 13.

15.4.3 Proper PPE, including the need for flash-fire-resistant garments, shall be in accordance with Section 8.6.

15.4.4* Cleaning operations shall avoid the formation of dust clouds.

N **15.4.5** Brushes used for cleaning operations shall be made of natural fiber.

15.4.6 Electrical classification shall be in accordance with Section 12.4.

N **15.4.7*** The removal of powder bed filters shall comply with 15.4.7.1 and 15.4.7.2.

N **15.4.7.1** Personnel involved in cleaning powder bed filters shall wear proper PPE, including gloves, that complies with NFPA 2112.

N **15.4.7.2** The protocol for changing powder bed filters and handling the waste stream shall be explicitly reviewed as part of the DHA.

15.5* Training.

Δ **15.5.1*** 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.

15.5.1.1 Operators shall receive this training prior to operation of the equipment.

N **15.5.1.2** The training of operators shall be documented.

N **15.5.1.3** When 3D printers are used by multiple operators, a listing of approved operators shall be posted at the machine.

15.5.1.4 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.

15.5.2* In addition to the requirements of Chapter 10, operators shall be trained in accordance with Section 9.8 of NFPA 652.

15.6 Emergency Response.

15.6.1 Emergency response shall be in accordance with Chapter 10, in addition to the equipment manufacturer's instructions.

15.6.2* Signs identifying the powder composition in the printer shall be posted in a location readily visible to emergency responders.

Chapter 16 Alkali Metals

16.1* General Provisions.

16.1.1 Retroactivity. The requirements of 16.1.2 through 16.1.4 shall apply to new and existing facilities.

16.1.2 Housekeeping.

16.1.2.1* Special Consideration. Alkali metals shall be kept away from sources of moisture.

16.1.3 Personal Protective Equipment (PPE). In addition to the requirements of this section, PPE shall be in accordance with Section 8.6.

16.1.3.1* PPE for Handling Solid Alkali Metals.

16.1.3.1.1 Personnel shall wear eye protection while handling solid alkali metals.

16.1.3.1.2 Personnel shall wear gloves while handling solid alkali metals.

16.1.3.1.3 Gloves shall have tight-fitting cuffs and shall be made of a material suitable for protection from caustic hazards.

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.

16.1.3.2* PPE for Handling Molten Alkali Metals.

16.1.3.2.1 Personal protective equipment shall be worn and shall be compatible with the hazards of molten alkali metals.

16.1.3.2.2* An external clothing layer that is impervious to body moisture shall be worn for protection from splash.

16.1.4 Reactivity.

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)].

16.1.4.2 Eutectic Reactions. (Reserved)

16.1.5 Management of Change. Management of change shall be in accordance with Section 8.12.

16.1.6 Alternative Methodologies. (Reserved)

16.1.7 Test Results. (Reserved)

16.1.8 Other.

16.2 Facility Design Requirements.

16.2.1 Building Construction.

16.2.1.1* Floor drains shall not be permitted.

16.2.1.2 Where molten alkali metals are handled, dispensed, or stored, the handling area shall be provided with compatible and nonreactive containment.

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.

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.

16.2.1.3 Separation from Water.

16.2.1.3.1 Piping permitted by 9.2.8.3.3 shall be constructed of steel.

16.2.1.3.2 A sprinkler system(s) deemed appropriate in accordance with 10.5.2 shall be permitted.

16.2.1.3.3 Portions of buildings where alkali metals are stored, handled, processed, or used shall be separated by watertight walls, ceilings, and door systems from adjacent areas where water can be present.

16.2.1.3.4 The floor shall be sloped in such a manner to prevent water from entering the alkali metals area.

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16.2.1.4 NFPA Hazard Identification Markings.

16.2.1.4.1 Alkali metal handling, processing, and storage areas having quantities greater than 2.3 kg (5 lb) shall have diamond markings as specified in NFPA 704 to make emergency responders aware of the presence of water-reactive materials within the area.

16.2.1.4.2 The diamond markings shall be at least 457.2 mm (18 in.) on each side with appropriate size numbers and symbols as specified in NFPA 704.

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16.2.2 Fire Protection.

16.2.2.1 Fire Protection. Fire protection shall be established in accordance with Chapter 10.

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 Chapter 10.

16.2.3 Dust Collection. (Reserved)

16.2.4 Hazard Analysis. The hazard analysis shall be in accordance with Chapter 7.

16.3 Primary Metal Production.

16.3.1 Reduction. (Reserved)

16.3.2 Melting and Casting.

16.3.2.1* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

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.

Δ **16.3.2.3** Molten alkali metal piping systems shall be designed in conformance with ASME B31.3, *Process Piping*.

16.3.2.3.1 All pump seals and flange gaskets shall be made of compatible materials.

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.

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.

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.

16.3.3 Refining. (Reserved)

16.4 Powder Production. (Reserved)

16.5 End Users of Powder. (Reserved)

16.6 Processing and Handling.

16.6.1 Machinery and Operations.

16.6.1.1* Where alkali metals are processed with a flammable or combustible liquid, the requirements of NFPA 30 shall also be followed for the flammable or combustible liquids.

16.6.1.2 Moisture Protection.

16.6.1.2.1 Solid alkali metals shall be protected from moisture during handling.

16.6.1.2.2* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

16.6.1.2.3* Only the amount of alkali metal needed for an individual task or procedure shall be removed from containers.

16.6.1.2.4* Surplus alkali metal shall be placed in a container protected from moisture and sealed immediately.

16.6.1.3 Machining and Operations. (Reserved)

16.6.2 Flake and Paste. (Reserved)

16.6.3 Plasma Spray Operations. (Reserved)

16.6.4 Transfer Operations.

16.6.4.1 General Precautions.

16.6.4.1.1 Alkali metals shall be handled only by trained personnel who are knowledgeable of the hazards associated with alkali metals.

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.

16.6.4.1.3 Access to alkali metal–handling areas by unauthorized personnel shall not be permitted.

16.6.4.1.4* Alkali metals shall not be handled in the presence of incompatible materials.

16.6.4.1.5 Dedicated storage of ordinary combustible materials or flammable or combustible liquids shall be prohibited in areas where alkali metals are handled, processed, or stored.

16.6.4.1.5.1 Quantities of dry mineral oil necessary for safe storage and handling shall be permitted where lithium is processed, handled, or stored.

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.

16.6.5 Processing Recycled Material. (Reserved)

16.7* Machining, Fabrication, Finishing, and Media Blasting.

16.7.1 Hot Work Operations.

16.7.1.1 Hot work operations shall be in accordance with Section 12.2.

16.7.2 Chip Processing. (Reserved)

16.7.3 Dust Collection. (Reserved)

16.8 Storage and Handling.

16.8.1* Storage of Product.

16.8.1.1 Alkali metals shall be handled, processed, and stored only in accordance with the requirements of this chapter.

16.8.1.2 Storage of Solid or Molten Alkali Metals.

16.8.1.2.1 General Precautions.

Δ **16.8.1.2.1.1*** Alkali metals shall be permitted to be stored in shipping containers that meet the requirements of *UN Recommendations on the Transport of Dangerous Goods: 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.

16.8.1.2.1.2 Alkali metals shall not be stored in containers previously used for the storage of incompatible materials.

16.8.1.2.1.3* Alkali metals shall not be stored in an area with incompatible materials.

16.8.1.2.1.4 Alkali metals in nonbulk containers shall not be stored outside.

16.8.1.3 Solid Alkali Metals Storage.

16.8.1.3.1 Solid alkali metals shall be stored only on the ground floor.

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.

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.

16.8.1.3.4 Containers shall be stored individually or on pallets in an arrangement that allows visual inspection for container integrity.

16.8.1.3.4.1 Containers on pallets shall be permitted to be stored in racks not more than 4.5 m (15 ft) high.

16.8.1.3.4.2 Containers on pallets and not stored in racks shall be stacked in a stable manner not to exceed three pallets high.

16.8.1.3.4.3 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.

16.8.1.3.4.4 Idle pallet storage shall not be permitted in alkali metal storage areas.

16.8.1.3.4.5 Idle metal pallets shall be permitted in alkali metal storage areas.

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.

16.8.2 Scrap Handling, Storage and Disposal. Alkali metals shall be handled, processed, and stored in accordance with the requirements of this chapter.

16.8.2.1 NFPA Hazard Identification Markings.

16.8.2.1.1 Alkali metal handling, processing, and storage areas having quantities greater than 2.3 kg (5 lb) shall have diamond markings as specified in NFPA 704 to make emergency responders aware of the presence of water-reactive materials within the area.

16.8.2.1.2 The diamond markings shall be at least 457.2 mm (18 in.) on each side with appropriate size numbers and symbols as specified in NFPA 704.

16.8.3 Recycling.

16.8.4 Chip Processing. (Reserved)

16.9* Fire and Explosion Protection.

16.9.1 Fire and explosion protection shall be in accordance with Chapter 10.

16.9.1.1* Alkali metal fire residues shall be stored in a designated and isolated location.

16.9.2 Housekeeping.

16.9.2.1 Dust Control. (Reserved)

16.9.2.2* Special Consideration. Alkali metals shall be kept away from sources of moisture.

16.9.3 Control of Ignition Sources.

16.9.3.1 Control of ignition sources shall be in accordance with Chapter 12.

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.

16.9.3.2.1* Alkali metal fire residues shall be disposed of within 7 days unless the AHJ allows longer storage.

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.

16.9.3.2.3 Alkali metal fire residues shall be disposed of in accordance with federal, state, and local regulations.

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.

16.9.3.2.5 Alkali metal fire residues shall be stored in metal containers that are recommended by the alkali metal manufacturer.

16.9.4* Hot Work Operations.

16.9.4.1 Hot work operations shall be in accordance with Section 12.2.

16.9.5 Control of Combustible Materials.

16.9.5.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

16.9.5.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

16.9.5.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

16.9.5.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

16.9.5.2 Ordinary Combustible Storage.

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.

16.9.5.2.2 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal waste.

16.9.5.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

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.

16.9.5.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitible shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

16.9.6 Inspection, Maintenance, and Training. (Reserved)

16.10 Other. (Reserved)

Chapter 17 Legacy Metals

17.1* General.

17.1.1 Reactivity.

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.

17.1.1.2 Reactive molten metals shall be contained in closed systems that prevent their unintentional contact with air or reactive materials.

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.

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)].

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.

17.1.5 Dust Collection. Dust collection shall be in accordance with Chapter 13.

17.1.6 Ignition Sources. Electrical power and ignition sources shall be in accordance with Chapter 12.

17.1.7 Hot Work.

17.1.7.1 Hot work operations shall be in accordance with Section 8.5, 12.2, and the requirements of this section.

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.

17.1.8 Fire Extinguishers. Portable fire extinguishers shall be in accordance with Chapter 10.

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17.2 Facility Design Requirements. Facility design shall be in accordance with 9.2.7, 9.2.8, and the requirements of this section.

17.2.1 Dust Hazard Analysis (DHA).

17.2.1.1 Dust hazard analysis shall be in accordance with Chapter 7 and the requirements of this section.

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.

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17.2.2 Building Construction.

17.2.2.1 Buildings that contain metals in a combustible form shall be constructed in accordance with the locally adopted building code.

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17.2.3 Protective Openings.

17.2.3.1 Means of egress shall be provided in compliance with NFPA *101*.

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17.3 Primary Metal Production (Smelting). This standard shall not apply to the primary production of aluminum and magnesium.

Δ **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.

17.3.1.1 Reactor vessels shall be air-cooled.

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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.

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N **17.3.1.3** All containers used to receive molten metal shall be cleaned and dried thoroughly before use.

17.3.1.4 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than that developed from the hazard analysis.

17.3.1.5 Combustible materials shall be minimized in the (sponge) collection area, well-ventilated, and free from other materials.

Δ **17.3.1.6** Dust resulting from the crushing of sponge shall be managed safely to minimize the risk of fires and explosions.

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N **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.

17.3.2 Refining. (Reserved)

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17.3.3* Melting and Casting.

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.

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.

17.3.3.3* Prevention of Molten Metal Contact with Foreign Materials.

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.

17.3.3.3.2 Crucible interiors and covers shall be maintained free of iron oxide scale, which could fall into the molten metal.

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N **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.

17.3.3.3.4 Melting pots and crucibles shall be inspected regularly.

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.

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N **17.3.3.3.6** Iron scale and metal spillage shall be minimized in furnaces.

N **17.3.3.4** Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

Δ **17.3.3.5** All molds shall be thoroughly preheated before pouring castings.

17.3.3.6 Extreme care shall be exercised when pouring molten metal castings to avoid spillage.

17.3.3.7 Personnel in areas where melting and casting occurs shall be evaluated for appropriate PPE per Section 8.6.

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17.3.3.8* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

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.

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17.3.3.10 Upper Chamber of the Furnace.

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.

17.3.3.10.2 The release pressure of the rupture disc shall be at a gauge pressure of 138 kPa (20 psi) maximum.

• **17.3.3.10.3** Means shall be provided to prevent the influx of air through the pressure-relief port.

• **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.

Δ **(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.

17.3.3.10.5 All furnace pits and bunkers shall be evaluated as confined spaces.

• **17.3.3.11* Molds and Crucibles.**

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.

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.

N **17.3.3.11.3** Molds (and crucibles) for metal casting (melting) shall be made of material that is compatible with molten metal.

N **17.3.3.11.4** Molds (and crucibles) shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

N **17.3.3.11.5** All pieces of metal shall be clean and dry when charged to reactors.

• **17.3.3.12* Residue.**

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.

17.3.3.12.2 The containers specified in 17.3.3.12.1 shall be stored so that any hydrogen gas generated vents freely.

17.3.3.13 Water Supply.

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.

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.

• **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.

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17.3.3.14 Vacuum Arc Remelt (VAR) and Electroslag Remelting (ESR).

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.

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.

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.

17.3.3.14.4 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

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

17.3.3.15 Electron Beam (EB) and Plasma Arc Melting (PAM). (Reserved)

17.3.3.16 Vacuum Induced Melting (VIM) and Skull. (Reserved)

• **17.4 Powder Production.**

17.4.1 General.

Δ **17.4.1.1** Where powder is present, good housekeeping practices shall be maintained. *(See Chapter 9.)*

N **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.

17.4.1.3 Combustible metal powder shall be handled to avoid spillage and the creation of airborne dust.

• Δ **17.4.1.4*** Each container for powders shall be conductive and covered while in storage or in transit within the facility.

Δ **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.

• *N* **17.4.1.6** Scoops, shovels, and scrapers used in the handling of powder shall be electrically conductive and shall be bonded and grounded.

N **17.4.1.7** Hand tools shall be made of spark-resistant materials.

N **17.4.1.8** When powder is being transferred between containers, the containers shall be bonded and grounded.

N **17.4.1.9** Equipment shall be constructed to mitigate the potential for ignition of metal powder.

N **17.4.1.10** Powder-handling or powder-processing areas shall not be used for the primary storage of metal powder.

N 17.4.1.11 Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in metal powder-processing areas.

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Δ **17.4.2 In-Plant Conveying of Powder.**

17.4.2.1 Containers.

Δ **17.4.2.1.1** In-plant transport or transfer of powders shall be done in covered conductive containers as described in 17.4.1.4.

17.4.2.1.2 Powered industrial trucks shall be selected in accordance with NFPA 505 and be consistent with Section 9.4.9.

17.4.2.1.3 All wheeled containers, hand trucks, and lift trucks shall be grounded.

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17.4.3 Pneumatic Conveying. Pneumatic conveying shall be in accordance with Section 13.5.

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17.4.4 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 13.5.1.

N **17.4.5 Dust Collectors.** Dust collectors shall be in accordance with Chapter 13.

17.4.6 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 13.5.2.

17.4.7 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 13.5.3.

17.4.8 Powder Collection. Powder collection shall be in accordance with Section 13.6.

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17.4.9 General Precautions.

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).

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.

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.

17.4.9.4* Frictional heating shall be minimized using lubrication, inspection programs, and maintenance programs and by techniques recommended by the equipment manufacturer.

17.4.10 Requirements for Machinery.

17.4.10.1 All metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

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 NFPA 652.

17.4.10.2.1 The requirement of 17.4.10.2 shall apply to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled.

17.4.10.2.2* Static-dissipative belts shall be used on belt-driven equipment.

17.4.10.3* Only grounded and bonded bearings, properly sealed against dust, shall be used.

17.4.10.4 Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

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.

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.

17.4.12 Charging and Discharging. All powder containers not used for shipping into or out of the plant shall be made of metal.

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17.4.13 Packaging and Storage.

17.4.13.1 Powder shall be stored in closed, non-combustible, non-lined steel drums or other closed conductive containers.

17.4.13.2 The containers shall be tightly sealed and stored in a dry location until ready for shipment or repacking.

N **17.4.13.3** Equipment shall be designed, constructed, installed, and operated to mitigate the potential for ignition of the metal.

Δ **17.4.14*** Only powder for immediate use shall be present in production areas.

Δ **17.4.14.1** Daily supplies of powder shall be allowed to be stored in the production area.

Δ **17.4.14.1.1** The powder shall be stored in covered containers and shall be segregated from other combustible materials.

17.4.14.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

17.4.14.1.3 The containers shall be protected from damage.

Δ **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.

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Δ **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.

Δ **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.

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 hazard analysis.

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.

Δ **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.

17.4.17.4 Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.

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.

N **17.4.18 Powder Handling.**

N **17.4.18.1** Special care shall be taken to prevent spills or dispersions that produce dust clouds.

N **17.4.18.2** Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

N **17.4.18.3** Hot zones of furnaces that handle metal powder in any form shall be provided with vacuum or inert atmospheres.

N **17.4.18.4** The furnaces shall be designed in accordance with NFPA 86.

N **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.

N **17.4.18.6** Only nonsparking tools and utensils shall be used in handling metal powder.

17.4.19* Dryers.

17.4.19.1 Dryers shall be constructed of noncombustible materials.

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

N **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.

17.4.19.4* Products of combustion, as a result of a collector fire, shall be considered when designing wet collector installations.

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.

17.4.19.6 Explosion protection shall be provided as specified in 17.4.16.

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.

17.4.19.8 Heated dryers shall have operating controls configured to maintain the temperature of the drying chamber within the prescribed limits.

17.4.19.9 Excess temperature–limit controls required in 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

17.4.19.10 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 17.4.19.9.

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

17.4.19.12 All automatic shutdowns required by 17.4.19.10 shall require manual reset before the dryer can be returned to operation.

Δ **17.4.19.13** If the powder being dried has been determined, in its current form, via test requirements in Chapter 5 of this standard, to be combustible, only dryers compatible with the DHA shall be allowed to be used.

17.4.20 Powder Production.

Δ **17.4.20.1** Care shall be exercised to avoid the presence of an isolated conductor in the vicinity of powder being handled.

Δ **17.4.20.2*** The use of humidifiers in facilities where dry powder is handled shall be considered.

Δ **17.4.20.3** Sintering furnaces that handle parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86.

17.4.20.4 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

17.4.20.5 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

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17.4.21 Electrical Installations. (Reserved)

17.4.22 Explosion Prevention and Protection.

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 NFPA 652 Chapter 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.

17.4.22.2 Where explosion protection is required per 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 explosion 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

17.4.22.3 If the method specified in 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.

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.

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.

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.

17.4.24 Personnel Safety Precautions.

17.4.24.1 PPE shall be in accordance with Section 8.6 and the requirements of this section.

Δ **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.

Δ **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.

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.

Δ **17.4.24.5*** Powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with powder.

Δ **17.4.24.6** Access to powder-handling areas by unauthorized personnel shall not be permitted.

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17.5 End Users of Powder.

N **17.5.1 General.** Processing, storage, and handling of combustible metal powders shall follow the requirements of this chapter in addition to the fire and explosion prevention and mitigation requirements in Chapters 8 through 16.

Δ **17.5.2 Powder Handling and Use.** The provisions of Section 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.

Δ **17.5.3 Storage.** Dry powder and paste shall be stored in accordance with the provisions of 17.8.1.

Δ **17.5.4* Handling.** The requirements of Section 17.5 shall apply to both regular and "nondusting" grades of powder, as well as to paste.

Δ **17.5.5** Where powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with Chapter 11.

Δ **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 Section 9.4.7.2.)*

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Δ **17.5.7*** Equipment shall be constructed to mitigate the potential for ignition of powder.

Δ **17.5.8** A hazards analysis shall be performed for areas where powder is present to determine risk factors and applicable controls.

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.

Δ **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.

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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.

Δ **17.5.12* Powder Storage.**

Δ **17.5.12.1** Powder-handling areas or powder-processing areas shall not be used for primary storage of powder.

17.5.12.1.1 Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in powder-processing areas.

Δ **17.5.12.2** Daily supplies of powder shall be allowed to be stored in the production area.

Δ **17.5.12.2.1** The powder shall be stored in covered containers and shall be segregated from other combustible materials.

17.5.12.2.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

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N **17.5.12.2.3** The containers shall be protected from damage.

17.5.12.3 Stacked Storage.

Δ **17.5.12.3.1** Where powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

17.5.12.3.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

Δ **17.5.12.4 Dry Powder Handling.**

Δ **17.5.12.4.1*** Precautions shall be taken to prevent spills or dispersions that produce dust clouds.

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Δ **17.5.12.5 Wet Powder Handling.** Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

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 80°C (176°F).

Δ **17.5.12.5.2** When drying powders under controlled atmospheric conditions (for example, vacuum or inert atmosphere) and when the temperature exceeds 80°C (176°F), the powder shall be cooled to less than 80°C (176°F) prior to exposure to air.

17.5.12.6 Heat Treatment and Passivation.

17.5.12.6.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of powder.

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.

17.5.12.6.3 Furnaces shall comply with NFPA 86.

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17.5.12.7 Personnel Safety Precautions.

17.5.12.7.1 Metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with powder.

Δ **17.5.12.7.2** Access to handling areas by unauthorized personnel shall not be permitted.

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.

Δ **17.5.12.8 Powder Heat Treatment and Sintering.**

Δ **17.5.12.8.1** After powder furnacing, the powder shall be passivated prior to exposure to air atmosphere.

Δ **17.5.12.8.2** Furnaced powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

Δ **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.

Δ **17.5.12.9* Heat Treatment and Sintering of Compacts.**

Δ **17.5.12.9.1*** Sintered compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

Δ **17.5.12.9.2** Sintered compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

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17.6 Processing and Handling.

17.6.1 Machining and Operations.

17.6.1.1* Where metals are processed with a flammable or combustible liquid, the requirements of NFPA 30 shall also be followed for the flammable or combustible liquids.

17.6.2 Requirements for Machinery.

17.6.2.1 All combustible metal dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

17.6.2.2* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

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

17.6.2.4* Wet Milling of Metal Powder. The requirements of 17.6.2.4.1 through 17.6.2.4.5 shall not apply to machining and rolling operations.

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.

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.

17.6.2.4.3 The dew point of the atmospheres in 17.6.2.4.1 and 17.6.2.4.2 shall be maintained below the point where condensation occurs.

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.

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.

17.6.3 Plasma Spray Operations.

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.

17.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

17.6.4 Transfer Operations.

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.

17.6.5 Processing Recycled Material. The requirements of Chapter 19 shall apply to processes handling recycled metal that is in a combustible form.

17.7* Machining, Fabrication, Finishing, and Media Blasting.

17.7.1 General Precautions.

Δ **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.

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.

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 17.1.3)* has been shown to be inapplicable to those metals through the performance of a hazard analysis.

17.7.2* Machining and Sawing Operations.

17.7.2.1* Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of metals.

17.7.2.1.1 The collected solids shall be moved to a designated storage or disposal area.

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.

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.

17.7.2.1.4 A hazards analysis shall be conducted to ensure that these operations do not contribute to fugitive dust accumulation.

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.

17.7.2.2 Cutting Tools.

17.7.2.2.1* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal.

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.

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.

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.

17.7.2.3 All machines shall be provided with a pan or tray to catch chips or turnings.

17.7.2.3.1 The pan construction shall be sufficient to minimize the potential for burn-through.

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.

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.

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.

17.7.2.4.1 During metal-machining operations, chips shall be removed from the point of generation by continuous or batch removal.

17.7.2.4.2 Periodic removal of metal chips from buildings and machinery shall be carried out as frequently as conditions warrant.

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.

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 17.1.3)* has been shown to be inapplicable for those metals through the performance of a hazard analysis.

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.

17.7.2.5 Coolant.

17.7.2.5.1 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

17.7.2.5.2* Flammable or combustible liquids shall be handled in accordance with NFPA 30.

17.7.2.5.3* Coolants with a flash point greater than 93°C (200°F) shall be permitted for wet grinding, cutting, or sawing operations where a hazard analysis has shown it to be acceptable.

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 19 L (5 gal) and shall be removed to a safe storage or disposal area.

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 93°C (200°F).

17.7.3* Machining Magnesium.

17.7.3.1 The specific requirements of 17.7.3 shall apply only to operations using magnesium.

17.7.3.2 Periodic removal of magnesium chips from buildings and machinery shall be carried out as frequently as conditions warrant.

17.7.3.3 Chips shall be removed to a safe storage or disposal area.

N 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.

17.7.3.4 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

• **17.7.3.5 Dust Collection.** Dust collection shall be in accordance with Chapter 13.

17.7.3.6* Machining.

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.

17.7.3.6.1.1 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.

17.7.3.6.1.2 Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

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.

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.

17.7.3.6.3.1 Side relief shall be 5 degrees.

17.7.3.6.3.2 End relief shall be from 10 degrees to 20 degrees.

17.7.3.6.4 If lubrication is needed, as in tapping or extremely fine grooving, a high-flash point lubricant shall be used.

17.7.3.6.4.1 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.

17.7.3.6.4.2 Special formulated coolant fluids (water–oil emulsions) that specifically inhibit the formation of hydrogen gas shall be permitted.

17.7.3.6.5 Where compressed air is used as a coolant, special precautions shall be taken to keep the air dry.

17.7.3.6.6 All machines shall be provided with a pan or tray to catch chips or turnings.

17.7.3.6.6.1 The pan or tray shall be installed such that it can be readily withdrawn from the machine in case of fire.

17.7.3.6.6.2 The pan shall be readily accessible for chip removal and for application of an extinguishing agent to control a fire.

17.7.3.6.6.3 During magnesium-machining operations, chips shall be removed from the point of generation by continuous or batch removal.

(A) Accumulation of chips at the point of generation shall not exceed 1.4 kg (3 lb) dry weight.

(B) All chips shall be stored in covered noncombustible containers and removed to a storage area in accordance with 17.8.3.

17.7.3.6.6.4 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.

17.7.3.7 Cleaning.

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.

17.7.3.7.2 Cleaning shall be done using soft brushes and conductive, nonsparking scoops and containers.

17.7.3.7.3* Vacuum cleaners shall not be used unless they are specifically listed for use with magnesium powder or dusts.

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.

17.7.3.8 Drawing, Spinning, and Stamping.

17.7.3.8.1 Reliable means to prevent overheating shall be provided where magnesium is heated for drawing or spinning.

17.7.3.8.2 Clippings and trimmings shall be collected at frequent intervals and placed in clean, dry steel or other noncombustible containers.

17.7.3.8.3 Fine particles shall be handled according to the requirements of Chapters 11 and 13.

17.7.3.9* Heat Treating.

17.7.3.9.1 A standard procedure for checking the uniformity of temperatures at various points within heat-treating furnaces shall be established.

17.7.3.9.2 Furnaces shall be checked prior to use and at regular intervals during use to identify undesirable hot spots.

17.7.3.9.3* Gas- or oil-fired furnaces shall be provided with combustion safety controls.

17.7.3.9.4 All furnaces shall have two sets of temperature controls operating independently.

17.7.3.9.4.1 One set of temperature controls shall maintain the desired operating temperature.

17.7.3.9.4.2* 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.

17.7.3.9.5 Magnesium parts to be put in a heat-treating furnace shall be free of magnesium turnings, chips, and swarf.

17.7.3.9.6 Combustible spacers on pallets shall not be used in a heat-treating furnace.

17.7.3.9.7* Aluminum parts, sheets, or separators shall not be included in a furnace load of magnesium.

17.7.3.9.8 There shall be strict adherence to the heat-treating temperature cycle recommended by the alloy manufacturer.

17.7.3.9.9* Molten salt baths containing nitrates or nitrites shall not be used for heat-treating magnesium alloys.

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.

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.

17.8 Storage and Handling.

N **17.8.1 Storage of Powder.**

17.8.1.1* Storage of materials in closed, noncombustible containers shall be permitted except as noted for sponge. *(See 17.8.1.11.2.)*

N **17.8.1.1.1** Powder shall be stored in covered containers.

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17.8.1.2 Containers from which a portion of powder has been removed shall be carefully covered and resealed.

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.

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17.8.1.4 Containers shall be kept free of contact with water or moisture.

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.

Δ **17.8.1.6 Storage with Incompatible Materials.**

17.8.1.6.1* Powder shall be segregated from incompatible materials and combustible materials.

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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.

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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.

17.8.1.8.1 Stacked storage shall be arranged to ensure stability.

17.8.1.8.2 Aisles shall be provided for maneuverability of material-handling equipment, for ready accessibility, and to facilitate incipient fire-fighting operations.

N **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.

N **17.8.1.8.4** Stack height shall not exceed 3.1 m (10 ft).

Δ **17.8.1.9** The available equipment shall be capable of moving the maximum weight of material (per pallet or container).

17.8.1.10 Leakage or condensation from roofs, floors, walls, drains, steam, water lines, or radiators shall be avoided.

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17.8.1.11 Sponge Storage.

17.8.1.11.1 Sponge shall be stored in closed metal containers.

17.8.1.11.2 Containers shall not be sealed unless they are inerted.

17.8.1.11.3 Storage of sponge shall comply with 17.8.1.

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Δ **17.8.2 Scrap Handling, Storage, and Disposal.** Scrap handling, storage, and disposal shall be in accordance with Chapter 19.

17.8.2.1 Open storage of sheets, plates, forgings, or massive pieces of scrap shall be permitted as they present no fire risk.

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17.8.2.2 Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

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.

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N **17.8.2.4** Sludge shall be disposed of in accordance with local, state, and federal regulations.

17.8.2.5 Storage of scrap, chips, fines, and dust that are ignitible shall be isolated and segregated from other combustible materials to prevent propagation of a fire.

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17.8.3 Other Production Materials.

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 17.8.6.

17.8.3.2 Sodium Operations. All sodium storage, handling, and processing operations shall be in accordance with Chapter 16.

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17.8.3.3 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30.

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17.8.3.4 Chlorine shall be handled and stored in accordance with accepted industry practice.

Δ **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.

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N **17.8.3.6** Containers shall be identified plainly and sealed tightly until used.

17.8.4 Recycling. Where a recycling facility handles metals in a combustible form, the requirements of Chapter 19 shall apply.

17.8.5 Chip Processing. (Reserved)

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N **17.8.6 Storage and Handling of Magnesium.** The specific requirements of 17.8.6 shall apply only to storage and handling of magnesium.

N **17.8.6.1* Storage of Pigs, Ingots, and Billets.**

N **17.8.6.1.1** The size of piles of magnesium pigs, ingots, and billets shall be limited.

N **(A)** Minimum aisle widths shall be based on the height of the pile per 17.8.6.1.2(H).

N **(B)** The pile height shall not exceed 7.1 m (20 ft).

N **17.8.6.1.2 Yard (Outdoor) Storage.**

N **(A)** Magnesium ingots shall be carefully piled on firm and generally level areas to prevent tilting or toppling.

N **(B)** Storage areas and yard pavement shall be well drained.

N **(C)** The storage area shall be kept free of grass, weeds, and accumulations of combustible materials.

N **(D)** Combustible flooring or supports shall not be used under piles of ingots.

N **(E)** The quantity of magnesium stored in any pile shall be kept to a minimum.

N **(F)** In no case, other than under the conditions of 17.8.6.1.2(G), shall the amount of magnesium stored exceed 45,400 kg (100,000 lb).

N **(G)** The quantities of magnesium stored shall be permitted to be increased up to a maximum of 454,000 kg (1,000,000 lb) 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 3.1 m (10 ft) but no less than 4.5 m (15 ft).
(3) The piles are not more than 3.1 m (10 ft) wide.

N **(H)** Aisle width shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).

N **(I)** Readily combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium ingots.

N **(J)** An open space equal to the height of the piles plus 3.1 m (10 ft) 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.

N **17.8.6.1.3* Indoor Storage.**

N **(A)** Indoor storage shall be in buildings of noncombustible construction.

N **(B)** Floors shall be well drained to prevent accumulation of water in puddles.

N **(C)** Supports and pallets used under piles of magnesium ingots shall be noncombustible.

N **(D)** The quantity of magnesium ingots stored in any one pile shall be kept to a minimum.

N **(E)** In no case, other than under the conditions of 17.8.6.1.3(F), shall the amount of magnesium stored exceed 23,000 kg (50,000 lb).

N **(F)** The quantities of magnesium stored shall be permitted to be increased up to a maximum of 227,800 kg (500,000 lb) per pile when the following requirements are met:

(1) The piles are not more than 3.1 m (10 ft) 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.

N **(G)** Aisle widths shall comply with 17.8.6.1.2(H).

N **(H)** Combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium pigs, ingots, and billets.

N **17.8.6.2 Storage of Heavy Castings.**

N **17.8.6.2.1** Except under the conditions of 17.8.6.2.2, buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

N **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.

N **17.8.6.2.3*** Floors shall be of noncombustible construction and shall be well drained to prevent accumulation of water in puddles.

N **17.8.6.2.4** All magnesium castings shall be clean and free of chips or fine particles of magnesium when being stored.

N **17.8.6.2.5 Storage Piles.**

N **(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 36 m^3 (1270 ft^3).

N **(B)** Aisles shall be maintained to allow for inspection and effective use of fire protection equipment.

N **17.8.6.2.6** Aisle width shall be at least one-half the height of the piles and at least 3.1 m (10 ft).

N **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.

N **17.8.6.3 Storage of Light Castings.**

N **17.8.6.3.1 Building Construction.**

N **(A)** Except under the conditions of 17.8.6.3.1(B), light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage by 7.7 m (25 ft).

N **(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 17.8.6.3.5.)*

N **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 28 m^3 (1000 ft^3).

N **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.

N **17.8.6.3.4** Aisle widths shall be at least one-half the height of the piles and at least 3.1 m (10 ft).

N **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.

N **17.8.6.4 Storage in Racks or Bins.**

N **17.8.6.4.1** Racks shall be permitted to be extended along walls in optional lengths.

N **17.8.6.4.2** Aisle spaces in front of racks shall be equal to the height of the racks.

N **17.8.6.4.3** All aisle spaces shall be kept clear.

N **17.8.6.4.4** Combustible rubbish, spare crates, and separators shall not be allowed to accumulate within the rack space.

N **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.

N **17.8.6.5 Storage of Scrap Magnesium.**

N **17.8.6.5.1** Paragraph 17.8.6.5 shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

N **17.8.6.5.2** Buildings used for the indoor storage of magnesium scrap shall be of noncombustible construction.

N **17.8.6.5.3** Dry magnesium scraps shall be kept well separated from other combustible materials.

N **(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.

N **(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.

N **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.

N **(A)** Sources of ignition shall be kept away from the top of the container and the vent.

N **(B)** Containers shall not be stacked.

N **17.8.6.5.5** Storage of dry scrap in quantities greater than 1.4 m^3 (50 ft^3) [six 208 L drums (six 55 gal drums)] shall be kept separate from other occupancies by fire-resistive construction without window openings or by an open space of at least 15 m (50 ft), and such buildings shall be well ventilated to avoid the accumulation of hydrogen in the event that the scrap becomes wet.

N **17.8.6.5.6** Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers, pending salvage.

N **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.

N **17.8.6.5.8** The use of automatic sprinklers in magnesium scrap storage buildings or areas shall be prohibited.

N **17.8.6.6 Storage of Magnesium Powder.**

N **17.8.6.6.1** Buildings used to store magnesium powder shall be of noncombustible, single-story construction.

N **17.8.6.6.2** The use of automatic sprinklers in magnesium powder storage buildings shall be strictly prohibited.

N **17.8.6.6.3** Magnesium powder shall be kept well separated from other combustible or reactive metals.

N **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.

N **17.8.6.6.5** Magnesium powder storage areas shall be kept dry and shall be checked for water leakage.

N **17.8.6.6.6*** Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 5.5 m (18 ft).

N **(A)** Storage shall be stacked in a manner that ensures stability.

N **(B)** Containers shall not be allowed to topple over.

N **17.8.6.7 Storage of Other Magnesium Products.**

N **17.8.6.7.1*** Paragraph 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.

N **17.8.6.7.2** Storage in quantities greater than 1.4 m^3 (50 ft^3) 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.

N **17.8.6.7.3** Magnesium products stored in quantities greater than 28 m^3 (1000 ft^3) shall be separated into piles, each not larger than 28 m^3 (1000 ft^3), with the minimum aisle width equal to the height of the piles but in no case less than 3.1 m (10 ft).

N **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 28 m3 (1000 ft3) 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 9 m (30 ft) of the magnesium

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17.9 Fire and Explosion Prevention.

17.9.1 Fire and explosion protection shall be in accordance with Chapter 10.

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Δ **17.9.2 Scope.** Section 17.9 shall apply to new and existing facilities where combustible dusts, pastes, and powders are present.

17.9.3 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 12.

17.9.4 Hot Work Operations. Hot work operations in facilities covered by this standard shall be in accordance with Section 12.2.

17.9.5 Control of Combustible Materials.

17.9.5.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30.

17.9.5.1.1 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems of 189 L (50 gal) or greater shall use a less hazardous hydraulic fluid with a flash point greater than 93°C (200°F).

17.9.5.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34.

17.9.5.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33.

17.9.5.2 Ordinary Combustible Storage.

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.

Δ **17.9.5.2.2** Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal.

17.9.5.2.3 Where ordinary combustible materials are necessary for the process and are stored in designated areas, 17.9.5.2.1 shall not apply.

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Δ **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.

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17.9.5.3 Removal of Combustible Metal Chips, Fines, Swarf, Paste, Powder, Dust, and Sweepings.

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.

17.9.5.3.2 Open storage of sponge, chips, fines, and dust that are readily ignitible shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

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Δ **17.9.5.4 Safety Inspection.**

N **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.

N **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.

Δ **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.

17.9.5.4.4 Records of the inspections specified in 17.9.5.4.1 and 17.9.5.4.3 shall be kept.

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Δ **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.

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Chapter 18 Other Metals

18.1 General Provisions.

18.1.1 Retroactivity. The requirements of 18.1.2 through 18.1.5 shall apply to new and existing facilities.

18.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 11.

18.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 8.6.

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.

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.

18.1.4.2 Eutectic Reactions. (Reserved)

18.1.4.3 Contact with Water. (Reserved)

18.1.5 Management of Change. Management of change shall be in accordance with Section 8.12.

18.1.6 Alternative Methodologies. (Reserved)

18.1.7 Test Results. (Reserved)

18.1.8 Other. (Reserved)

18.2 Facility Design Requirements.

18.2.1 Dust Collection. Dust collection shall be in accordance with Chapter 13.

18.2.2 Hazard Analysis. Hazard analysis shall be in accordance with Chapter 7.

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18.3 Primary Metal Production.

18.3.1 Reduction. (Reserved)

18.3.2 Melting and Casting.

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 overtemperature of the melting crucible.

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.

18.3.2.3 Buildings used for the melting and casting of metals shall be noncombustible.

18.3.2.4 Floors shall be kept free of standing water.

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.

18.3.2.6 Ovens and furnaces shall comply with NFPA 86.

18.3.2.7 Fuel supply lines shall comply with NFPA 54.

18.3.2.8 Use of flammable and combustible liquids shall comply with NFPA 30.

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.

18.3.2.10 Crucible interiors and covers shall be maintained free of metal oxides scale that exothermically react with the molten metal.

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.

18.3.2.12 Pots and Crucibles.

18.3.2.12.1 Melting pots and crucibles shall be inspected regularly.

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.

18.3.2.13 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

18.3.2.14 Extreme care shall be exercised in pouring metal castings, to avoid spillage.

18.3.2.15 All molds shall be thoroughly preheated before pouring.

18.3.2.16 Operators' Garments.

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.

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.

18.3.3 Refining. (Reserved)

18.4 Powder Production.

18.4.1 Handling and Conveying of Powder.

18.4.1.1 Where powder is present, good housekeeping practices shall be maintained.

18.4.1.2 Powder shall be handled so as to avoid spillage and the creation of airborne dust.

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.

18.4.1.4 Each container for powders shall be conductive and covered while in storage or in transit.

18.4.1.5 When powders are being charged to or discharged from machines, the containers shall be bonded to the grounded machine.

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.

18.4.2 Portable Containers.

18.4.2.1 In-plant transport of metal powders shall be done in covered conductive containers as described in 18.4.1.4.

18.4.3 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 13.5.1.

18.4.4 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 13.5.2.

18.4.5 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 13.5.3.

18.4.6 Powder Collection. Powder collection shall be in accordance with Section 13.6.

18.5 End Users of Powder.

18.5.1 Powder Handling and Use.

18.5.1.1 Scope. The provisions of Section 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.

18.5.1.2 Storage. Dry powder and paste shall be stored in accordance with the provisions of Section 18.9.

18.5.1.3* Handling. The requirements of Section 18.5 shall apply to both regular and "nondusting" grades of powder, as well as to paste.

18.5.1.4 Where powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with Chapter 11.

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.

18.5.1.6 Powered industrial trucks shall be selected in accordance with NFPA 505 and consistent with 9.4.9.

18.5.2 General.

18.5.2.1* Equipment shall be constructed to mitigate the potential for ignition of the powder.

18.5.2.2 A hazards analysis shall be performed for areas where powder is present to determine risk factors and appropriate controls.

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.

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.

18.5.2.5* Spark-resistant tools shall be used.

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.

18.5.3 Powder Storage.

18.5.3.1 Daily supplies of powder shall be allowed to be stored in the production area.

18.5.3.1.1 The powder shall be stored in covered containers and shall be segregated from other combustible materials.

18.5.3.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

18.5.3.1.3 The containers shall be protected from damage.

18.5.3.2 Stacked Storage.

18.5.3.2.1 When powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

18.5.3.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

18.5.4 Dry Powder Handling.

18.5.4.1* Precautions shall be taken to prevent spills or dispersions that produce dust clouds.

18.5.4.2 Sintering furnaces that handle compacted powder shall be installed and operated in accordance with NFPA 86.

18.5.4.2.1 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

18.5.4.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

18.5.5 Handling of Wet Powder by End Users.

18.5.5.1 When water-wetted powder is air-dried at atmospheric pressure, the temperature shall not exceed 80°C (176°F).

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 80°C (176°F).

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 80°C (176°F), the powder shall be cooled to less than 80°C (176°F) prior to exposure to air.

18.5.6 Heat Treatment and Passivation.

18.5.6.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of the powder.

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.

18.5.6.3 Furnaces shall comply with NFPA 86.

18.5.7* Personnel Safety Precautions.

18.5.7.1 The metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with that particular metal.

18.5.7.2 Access to metal-handling areas by unauthorized personnel shall not be permitted.

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.

18.5.8 Powder Heat Treatment and Sintering.

18.5.8.1 After powder furnacing, the powder shall be passivated prior to exposure to air atmosphere.

18.5.8.2 Furnaced powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

18.5.9* Heat Treatment and Sintering of Compacts.

18.5.9.1* Sintered compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

18.5.9.2 Sintered compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

18.5.10 Safety Precautions.

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.

18.5.10.2 The alternative cooling system specified in 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.

18.6 Processing.

18.6.1 Machining and Operations.

18.6.1.1 Requirements for Machinery.

18.6.1.2 All combustible metal dust–producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

18.6.1.3* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

18.6.1.4 Bearings.

18.6.1.4.1* Ball or roller bearings shall be sealed against dust.

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.

18.6.1.5 Clearances between moving surfaces that are exposed to paste, powder, or dust shall be maintained to prevent rubbing or jamming.

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.

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

18.6.2 Flake and Paste.

18.6.2.1 Machinery and Operations.

18.6.2.1.1* Wet Milling of Metal Powder. The requirements of 18.6.2.1.1.1 through 18.6.2.1.1.6 shall not apply to machining and rolling operations.

18.6.2.1.1.1* 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.

18.6.2.1.1.2* 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.

18.6.2.1.1.3 The dew point of the atmospheres in 18.6.2.1.1.1 and 18.6.2.1.1.2 shall be maintained below the point where condensation occurs.

18.6.2.1.1.4 Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes, a conductive lubricant, or other applicable means.

18.6.2.1.1.5* 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.

18.6.2.1.1.6 Solvent or slurry pumps shall be installed with controls that ensure that a flow exists and that the pumps run with safe operating temperatures.

18.6.2.2 Electrical Equipment.

18.6.2.2.1 When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

18.6.2.2.2* Wet solvent milling areas or other areas where combustible or flammable 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.

18.6.3 Plasma Spray Operations.

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.

18.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

18.6.4 Transfer Operations.

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.

18.6.4.2 Prevention of Fugitive Dust Accumulations. See 18.1.2.

18.6.5 Processing Recycled Material. The requirements of Chapter 19 shall apply to processes handling recycled metal that is in a combustible form.

18.7* Machining, Fabrication, Finishing, and Media Blasting.

18.7.1 Hot Work Operations.

18.7.1.1 Hot work operations in facilities covered by this standard shall be in accordance with Section 12.2.

18.7.2 General Precautions.

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.

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.

18.7.3 Chip Production and Processing.

18.7.3.1 Machining and Sawing Operations.

18.7.3.2 Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal.

18.7.3.3 Sawing, grinding, and cutting equipment shall be grounded.

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.

18.7.3.5 Coolant.

18.7.3.5.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

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 19 L (5 gal) and shall be removed to a safe storage or disposal area.

18.7.4 Dust Collection. Dust collection shall be in accordance with Chapter 13.

18.8 Storage and Handling.

18.8.1 Storage of Combustible Metal Powder.

18.8.1.1 Buildings used to store metal powder shall be of noncombustible construction.

18.8.1.2 The use of automatic sprinklers in metal powder storage buildings shall be prohibited.

18.8.1.3 Metal powder shall be kept separated from other ordinary combustibles or incompatible materials.

18.8.1.4 Metal powder shall be stored in closed steel drums or other closed noncombustible containers.

18.8.1.5 Where the metal powder is reactive with water, metal-powder storage areas shall be kept dry.

18.8.1.6* Where metal powder in drums is stacked for storage, the maximum height shall not exceed 3.7 m (12 ft).

18.8.1.6.1 Storage drums shall be stacked in a manner that ensures stability.

18.8.1.6.2 Under no circumstances shall containers be allowed to topple over.

18.8.1.7* Storage of Other Metal Products.

18.8.1.7.1 Storage in quantities greater than 1.4 m^3 (50 ft^3) 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.

18.8.1.7.2 Metal products stored in quantities greater than 28 m^3 (989 ft^3) shall be separated into piles, each not larger than 28 m^3 (989 ft^3), with the minimum aisle width equal to the height of the piles but not less than 3.1 m (10 ft).

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 28 m^3 (989 ft^3) 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 9 m (30 ft) of the metal

18.8.2 Scrap Handling, Storage, and Disposal.

18.8.2.1 Storage of Combustible Scrap Metal.

18.8.2.1.1 The requirements of 18.8.2.1 shall apply to the storage of scrap metal in the form of solids, chips, turnings, swarf, or other fine particles.

18.8.2.1.2 Buildings used for the indoor storage of metal scrap shall be of noncombustible construction.

18.8.2.1.3 Scraps shall be kept well separated from other combustible materials.

18.8.2.1.3.1 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.

18.8.2.1.3.2 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.

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.

18.8.2.1.4.1 Sources of ignition shall be kept away from the container vent and top.

18.8.2.1.4.2 Containers shall not be stacked.

18.8.2.1.5 Storage of dry scrap in quantities greater than 1.4 m^3 (50 ft^3) [six 208 L drums (six 55 gal drums)] shall be kept separate from other occupancies by fire-resistive construction or by an open space of at least 15 m (50 ft).

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.

18.8.2.1.7 Solid metal scrap, such as clippings and castings, shall be stored in noncombustible bins or containers.

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.

18.8.2.1.9 The use of automatic sprinklers in metal-scrap storage buildings or areas shall be prohibited.

18.8.3 Recycling. (Reserved)

18.8.4 Chip Processing. (Reserved)

18.9 Fire and Explosion Prevention.

18.9.1 Fire and explosion prevention shall be in accordance with Chapter 10.

18.9.2 Control of Ignition Sources. (Reserved)

18.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 12.2.

18.9.4 Control of Combustible Materials. (Reserved)

18.9.5 Inspection, Maintenance, and Training.

18.9.5.1 Emergency Procedures. Emergency procedures shall be in accordance with Chapter 10.

18.9.5.1.1 Emergency procedures to be followed in case of fire or explosion shall be established.

18.9.5.1.2 All employees shall be trained in the emergency procedures.

18.10 Other. (Reserved)

Chapter 19 Recycling and Waste Management Facilities

19.1* General Provisions.

19.1.1 Retroactivity. The requirements of this chapter 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.

19.1.2 A combustible metal or metal dust hazard shall be identified by testing in accordance with Chapters 4 and 5 prior to application of any of the provisions of this chapter.

19.1.3 For facilities recycling or providing treatment or disposal services, the requirements of Chapters 6 through 12 shall also apply.

19.2 Recycling and Waste Management of Combustible Metal — Collection, Storage, and Handling of Fines Generated During Scrap Receiving, Storage, Recycling, and Waste Treatment.

19.2.1 Receiving Criteria. Incoming material shall be inspected for acceptance criteria.

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

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

19.2.1.3 The acceptance criteria shall be documented and available for review by the AHJ.

19.2.2 Rejected Material.

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.

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.

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.

19.3 Storage of Combustible Metals for Recycling and Waste Management.

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.

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.

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

19.3.4 The tracking records shall be available for inspection by the authority having jurisdiction.

19.3.5 Area and container labels or identification shall reference the appropriate material safety data sheets (MSDSs) on file.

19.3.6 Buildings used for the indoor storage of combustible metal shall be of noncombustible construction and shall meet the requirements of 9.2.7.

19.3.7 Solid combustible metals, such as clippings and castings, shall be stored in noncombustible bins or containers.

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.

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.

19.3.10* Combustible metals delivered for recycling or waste disposal that are stored on-site shall be identified as wet or dry.

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.

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.

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.

19.3.11.3 Outside storage of dry combustible metals shall be permitted if such storage is separated from buildings or personnel.

19.3.11.4 Storage of dry combustible metals in quantities greater than 1.4 m^3 (50 ft^3) [six 208 L drums (six 55 gal drums)] shall be kept separate from other occupancies by fire-resistive construction or by an open space of at least 15 m (50 ft).

19.3.11.5 Quantity Separation Distance. (Reserved)

19.3.12 Wet Combustible Metals Storage.

19.3.12.1 Wet combustible metals shall be stored at an outside location identified for that use.

19.3.12.2 Open flames and sparks shall be kept 15 m (50 ft) away from the container unless a hot-work permit allows an open flame within 15 m (50 ft).

19.3.12.3* Combustible metals that are received wet shall be kept under water in a covered and vented container.

19.3.12.4 Containers of wet combustible metals shall not be stacked.

19.3.12.5 Quantity Separation Distance. (Reserved)

19.3.13 Container Limits.

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 3.1 m (10 ft) in height.

19.3.13.2 The maximum weight of any material container and/or pallet shall be capable of being moved by the available equipment.

19.3.13.3 Stacked storage shall be arranged to ensure stability.

19.3.13.3.1 Aisles shall be provided for maneuverability of material handling equipment, for accessibility, and to facilitate fire-fighting operations.

19.4 Sample Identification and Collection for Metals in a Combustible Form.

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 Chapter 5 to determine whether it is a combustible metal.

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.

19.4.3* In recycling facilities where combustible metals are processed, samples shall be collected that represent a "worst case" scenario.

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.

19.4.5 Samples collected shall be promptly submitted for testing as dust tends to oxidize over time.

19.5 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 8.6.

19.6 Reactivity.

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.

19.6.2 Contact with Water.

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.

19.6.3 Thermite Reaction.

19.6.3.1* Caution shall be exercised in the mixing of metal fines and metal oxides [e.g., iron oxide (rust)].

19.7 Management of Change. Management of change shall be in accordance with Section 8.12.

19.8 Facility Design Requirements.

19.8.1 Building Construction.

19.8.1.1 Where dust is present, the buildings specified in 17.8.1.2 shall be designed so that all internal surfaces are readily accessible, to facilitate cleaning.

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19.8.2 Electrical Classification.

19.8.2.1 Electrical classification shall be in accordance with Section 12.4.

19.8.3 Hazard Analysis. Hazard analysis shall be in accordance with Chapter 7.

19.9 Emergency Preparedness.

19.9.1 Procedures.

19.9.1.1 Emergency procedures shall be established to address fire and explosion events in accordance with Sections 10.8 and 10.7.

19.9.1.2 The emergency procedures shall be documented.

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 10.5.3.5 shall be superseded.

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 to 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.

19.9.2* Training.

19.9.2.1 All employees shall be trained in the emergency procedures and the hazards of combustible metals.

19.9.2.2 Training shall be documented and available for inspection by the authority having jurisdiction.

19.10 Processing.

19.10.1 Control of ignition sources shall be in accordance with Chapter 10.

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.

19.10.1.2* Documentation of the determination in 19.10.1.1 shall be maintained and available for review by the authority having jurisdiction.

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 Chapter 19.

19.10.1.4 For all other recycled combustible metal and alloy processing, the requirements of Chapter 18 shall also apply.

19.10.1.5 Combustible or flammable liquids resulting from recycling of combustible metals shall be handled and stored in accordance with NFPA 30.

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.

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.

19.10.2 Machining and Operations.

19.10.2.1 Requirements for Machinery.

19.10.2.2 All combustible metal dust–producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

19.10.2.3 All machinery and equipment shall be installed in accordance with *NFPA 70*.

19.10.2.4* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

19.10.2.5 Bearings.

19.10.2.5.1* Ball or roller bearings shall be sealed against dust.

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.

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.

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.

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.

19.10.3 Transfer Operations.

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.

19.10.3.2 The container shall be grounded and bonded and nonsparking tools shall be used.

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.

19.10.4 Electrical Equipment.

19.10.4.1 All electrical wiring and equipment shall be in accordance with Chapter 12.

19.10.5 Chip Processing. (Reserved)

19.10.6 Machining and Sawing Operations.

19.10.6.1* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with the metal being processed.

19.10.6.2* Sawing, grinding, and cutting equipment shall be grounded.

19.10.7 Coolant.

19.10.7.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

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.

19.10.8 Dust Collection.

19.10.8.1 Dust collection shall be in accordance with Chapter 13.

19.11 Fire and Explosion Prevention.

19.11.1 The requirements of Chapter 10 shall apply.

19.11.2 Housekeeping.

19.11.2.1 The requirements of Chapter 11 shall apply.

19.11.3 Control of Metals in a Combustible from Finishing Operations.

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.

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.

19.11.4 Inspection, Maintenance, and Training.

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.

19.11.4.2 Records shall be kept of the inspections conducted in 19.11.4.

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 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.1.1.1 Any metal in a fine enough form can be combustible and/or explosible.

A.1.1.2.2 Ignitible fibers/flyings, as defined in *NFPA 70* and NFPA 499, do not present a flash-fire hazard or explosion hazard and are not included in the definition of combustible dust in this standard. Ignitible fibers/flyings present a fire hazard, so locations are classified differently and the electrical installation includes additional restrictions compared to combustible fibers/flyings. Ignitible metal fibers/flyings would be anticipated to be identified as a combustible metal in accordance with Chapter 5.

N **A.1.1.2.3** Operations such as welding, laser cutting, and plasma cutting should be considered to be within the scope of this standard unless the fumes collected from these processes can be shown to meet the requirements for exclusion in 5.2.4.

Δ **A.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.1.1.3(a) and Table A.1.1.3(b).]*

Δ **A.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, flammable liquids, 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.

NFPA 652 provides a minimum threshold below which metal-containing mixtures are not subject to review by NFPA 484. While NFPA 484 might not be applicable to a particular mixture, the mixture could be included in the scope of other NFPA standards, including but not limited to NFPA 61, NFPA 120, NFPA 495, NFPA 654, and NFPA 655.

Δ **Table A.1.1.3(a) 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.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 NFPA 484. Mixtures where the primary hazard is from nonmetals and the mixture behaves as a nonmetal might be covered by other commodity-specific standards. The criteria in 1.1.6.2(1), 1.1.6.2(2), and 1.1.6.2(3) determine whether the mixture can be extinguished using conventional fire-fighting measures commonly prescribed in other standards. See 10.5.3.1.1 for additional information on the criteria in 1.1.6.2(1) and 1.1.6.2(2). List item 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 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.

Δ Table A.1.1.3(b) Explosibility Properties of Metals

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

(continues)

Δ Table A.1.1.3(b) *Continued*

Material	Median Diameter (μm)	K_{St} (bar-m/s)	P_{max} (bar g)	Cloud Ign Temp (°C)	MIE (mJ)	MEC (g/m³)	VDI Combustibility Class[2]	LOC[1] (v%)	Data Source
Zinc (from collector)	10	176	7.3	—	—	125	BZ 2		Eckhoff
Zinc (from Zn coating)	19	85	6	800	—	—	BZ 2		Eckhoff
Zinc (from Zn coating)	21	93	6.8	790	—	250	—		Eckhoff
Zirconium	<44	—	5.2	20	5	45	—	Ignites in N_2 & CO_2	BuMines RI 6516
Zirconium (Zircalloy-2)	50	—	3.0	420	30	—	—	—	BuMines RI 6516

Notes:
(1) Limiting Oxygen Concentration. The letter in parenthesis in the LOC column denotes the inert gas used to reduce the oxygen concentration as follows: Ar = argon, C = carbon dioxide, N = nitrogen.
(2) VDI Guidelines 2263, Part 1, *Test Methods for the Determinations of Safety Characteristics Dusts*, classes are as follows:
(a) BZ1 No self-sustained combustion
(b) BZ2 Local combustion of short duration
(c) BZ3 Local sustained combustion, but no propagation
(d) BZ4 Propagating smoldering combustion
(e) BZ5 Propagating open flame
(f) BZ6 Explosive combustion
(3) BGIA is the GESTIS-DUST-EX database maintained by BGIA.
(4) Cashdollar, K., and I. Zlochower, "Explosion Temperatures and Pressures of Metals and Other Elemental Dust Clouds," *Journal of Loss Prevention in the Process Industries*, vol. 20, 2007.

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 standard, either NFPA 654 or some other combustible dust 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.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 promulgating 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.1.1.11 A combustible metal is a metal that meets the criteria for combustibility as defined in Chapter 5. The quantities listed in Table 1.1.11 are for the entire occupancy, not for individual fire control areas. This table is not intended to provide the MAQ. This standard 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 1.1.11 can still pose hazards, but those hazards might not warrant the full extent of the NFPA 484 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 NFPA 484 and metal storage, transfer, and emergency response requirements, even when the threshold has not been met.

A.1.5.2 The requirements identified in Chapter 10 and Chapter 19 are applicable to new and existing facilities.

A.1.7.2 A given equivalent value could be an approximation.

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

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

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

A.3.3.3 Air-Material Separator (AMS). Examples include cyclones, bag filter houses, dust collectors, and electrostatic precipitators. [**652,** 2019]

A.3.3.4 Air-Moving Device (AMD).

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

[**652,** 2019]

A.3.3.9.1 Heavy Casting. Castings less than 11.3 kg (25 lb) are considered light castings.

A.3.3.10 Centralized Vacuum Cleaning System. This system normally consists of multiple hose connection stations hard-piped to an AMS located out of the occupancy area. Positive displacement or centrifugal AMDs can be used to provide the negative pressure airflow. The hoses and vacuum cleaning tools used with the system should be designed to be conductive or static-dissipative to minimize any risk of generating an ignition source. Low minimum ignition energy (MIE) materials (e.g., many powder or dust form metals) should be given special considerations 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.

A.3.3.11 Chips. 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.

Δ **A.3.3.12 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. Ignitible fibers/flyings, as defined in *NFPA 70* and NFPA 499, do not present a flash-fire or explosion hazard and are not included in the definition of combustible dust in this standard. Ignitible fibers/flyings present a fire hazard, so locations are classified differently and the electrical installation includes additional restrictions compared to combustible fibers/flyings. [**652,** 2019]

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 CO_2 or nitrogen. [**652,** 2019]

Dusts traditionally were defined as material 420 μm or smaller (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with the smallest dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration 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 deflagration hazard. Many particulates accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Therefore, it can be inferred that any particulate that has 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 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 of NFPA 652 has additional information on testing requirements. [**652,** 2019]

There is some possibility that a sample will result in a false positive in the 20 L sphere when tested by the ASTM E1226 screening test or the ASTM E1515 test. This is due to the high energy ignition source overdriving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale (≥1 m^3) enclosure, which is less susceptible to overdriving and thus will provide more realistic results. [**652,** 2019]

This possibility for false positives has been known for quite some time and is attributed to "overdriven" conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on a 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from the 1 m^3 chamber for most dusts. In fact, the U.S. standard for 20 L testing (ASTM E1226) states, "The objective of this test method is to develop data that can be correlated to those from the 1 m^3 chamber (described in ISO 6184-1 and VDI 3673)..." ASTM E1226 further states, "Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and P_{max} parameters are known in the 1 m^3 chamber." [**652,** 2019]

NFPA 68 also recognizes this problem and addresses it stating that "the 20 L test apparatus is designed to simulate results of the 1 m^3 chamber; however, the igniter discharge makes it problematic to determine K_{St} values less than 50 bar-m/sec. Where the material is expected to yield K_{St} values less than 50 bar-m/sec, testing in a 1 m^3 chamber might yield lower values." [**652,** 2019]

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. [**652,** 2019]

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

[**652,** 2019]

If the deflagration is confined and produces a pressure sufficient to rupture the confining enclosure, the event is, by definition, an "explosion." [**652,** 2019]

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

(1) MEC
(2) MIE
(3) Particle size distribution
(4) Moisture content as received and as tested
(5) Maximum explosion pressure at optimum concentration
(6) Maximum rate of pressure rise at optimum concentration
(7) K_{St} (normalized rate of pressure rise) as defined in ASTM E1226
(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

[**652,** 2019]

It is important to keep in mind that as a particulate is processed, handled, or transported, the particle size generally decreases due to particle attrition. Therefore, it is often necessary to evaluate the explosibility of the particulate at multiple points along the process. Where process conditions dictate the use of oxidizing media other than air, which is nominally taken as 21 percent oxygen and 79 percent nitrogen, the applicable tests should be conducted in the appropriate process-specific medium. [**652,** 2019]

A.3.3.13 Combustible Fibers/Flyings. Section 500.5 of *NFPA 70* defines a Class III location. Combustible fibers/flyings can be similar in physical form to ignitible 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,** 2021]

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 ignitible fiber/flying, as defined in 3.3.44. 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,** 2021]

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.

A.3.3.14.1 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.

A.3.3.14.3 Metal Dust. Dust from some processes may 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.

A.3.3.15 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. [**652,** 2019]

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. [**652,** 2019]

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. [**652,** 2019]

For the purposes of this document, the term *particulate solid* does not include an upper size limitation. This is intended to encompass all materials handled as particulates, including golf balls, pellets, wood chunks and chips, and so forth. [**652,** 2019]

The term *particulate solid* is intended to include those materials that are typically processed using bulk material handling techniques such as silo storage, pneumatic or mechanical transfer, etc. While particulate solids can present a fire hazard, they are unlikely to present a dust deflagration hazard unless they contain a significant fraction of dust, which can segregate and accumulate within the process or facility. [**652,** 2019]

Dusts traditionally were defined as material 420 μm or smaller (i.e., capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 μm (i.e., capable of passing through a U.S. No. 35 standard sieve) is now considered an appropriate size criterion. Particle surface area-to-volume ratio is a key factor in determining the rate of combustion. Combustible particulate solids with a minimum dimension more than 500 μm generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameters usually do not pass through a 500 μm sieve, yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charges in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently, it can be inferred that any particulate that has a minimum dimension less than or equal to 500 μm could behave as a combustible dust if suspended in air or in the process-specific oxidizer. If the minimum dimension of the particulate is greater than 500 μm, it is unlikely that the material would be a combustible dust, as determined by test. [**652,** 2019]

Typically, the term *fines* refers to the fraction of material that is below 75 μm or that will pass through a 200-mesh sieve. Alternatively, fines can be characterized as the material collected from the final dust collector in a process or the material collected from the highest overhead surfaces in a facility. Fines typically represent a greater deflagration hazard than typical dusts of the same composition because they are more likely to remain suspended for an extended period of time and to have more severe explosion properties (higher K_{St}, lower MIE, etc.). [**652,** 2019]

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. Ignitible 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. Ignitible 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 NFPA 652. Combustible fibers/flyings as defined in NFPA 499 are included in the term *combustible dust* as used and defined in NFPA 652. [**652,** 2019]

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. Ignitible 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. [**652,** 2019]

N **A.3.3.17 Conductive.** A typical threshold for solid materials of construction would be a volume resistivity less than 10^5 ohm-m. [**652**, 2019]

A.3.3.19 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

N **A.3.3.23 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. [**652**, 2019]

A.3.3.26.1 Dust Collection System. A typical dust collection system consists of the following:

(1) Hoods — devices designed to contain, capture, and control airborne dusts by using an induced airflow in close proximity to the point of dust generation (local exhaust zone) to entrain fugitive airborne dusts.
(2) Ducting — includes, but is not limited to, piping, tubing, and fabricated duct, used to provide the controlled pathway from the hoods to the dust collector (AMS). Maintaining adequate duct velocity [usually above 1219 m/min (4000 ft/min)] is a key factor in the proper functioning of the system.
(3) Dust collector — an AMS designed to separate 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 or gas 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 (such a system would be either a pneumatic conveying/transfer system or centralized vacuum cleaning system). Thus, material loading must be minimal compared to the volume or mass of airflow.

A.3.3.26.4 Dust Hazards Analysis (DHA). In the context of this definition it is not intended that the dust hazards analysis (DHA) must comply with the process hazards analysis (PHA) requirements contained in OSHA regulation 29 CFR 1910.119, "Process Safety Management of Highly Hazardous Chemicals." While the DHA can comply with OSHA PHA requirements, other methods can also be used *(see Annex B of NFPA 652)*. 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. [**652,** 2019]

A.3.3.28 Explosible. For dusts, explosibility is determined as described in Section 5.5. See also 5.4.3 in NFPA 652. For hybrid mixtures, see NFPA 68.

A.3.3.32 Fire-Resistive. The requirements are described in NFPA 220.

A.3.3.34 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.1.1.3(a)]*. 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 hazard analysis (DHA).

A.3.3.42 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. [**654,** 2020]

The resulting dust-vapor mixture is called a *hybrid mixture* and is discussed in NFPA 68. In certain circumstances, hybrid mixtures can be deflagrable, even if the dust is below the MEC and the vapor is below the LFL. Furthermore, dusts determined to be nonignitible by weak ignition sources can sometimes be ignited when part of a hybrid mixture. [**654,** 2020]

Examples of hybrid mixtures are a mixture of methane, coal dust, and air or a mixture of gasoline vapor and gasoline droplets in air. [**654,** 2020]

N **A.3.3.43 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:**100]

A.3.3.44 Ignitible Fibers/Flyings. Section 500.5 of *NFPA 70* defines a Class III location as one where ignitible fibers/flyings are present, but not likely to be in suspension in the air in quantities sufficient to produce ignitible 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,** 2021]

The zone classification system does not address ignitible fibers/flyings. Where these are present, the user should consider installation in accordance with Article 503 of *NFPA 70*. [**499,** 2021]

A.3.3.45 Incipient-Stage Fire. 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.

Δ **A.3.3.46 Industry- or Commodity-Specific Standard.** It is possible that within a single building or enclosure more than one industry- or commodity-specific NFPA standard could apply. The following documents are commonly recognized as commodity-specific standards:

(1) NFPA 61, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*

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

[**652,** 2019]

N **A.3.3.47.1 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. [**652,** 2019]

N **A.3.3.47.2 Rigid Intermediate Bulk Container (RIBC).** These are often called composite IBCs, which is the term used by the U.S. Department of Transportation (DOT). The term rigid nonmetallic intermediate bulk container denotes an all-plastic single-wall IBC that might or might not have a separate plastic base and for which the containment vessel also serves as the support structure. [**652,** 2019]

A.3.3.49.2 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 flammable or 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 combustible liquids and vapors.

Δ **A.3.3.49.3 Spark-Resistant Material.** See AMCA Standard 99, *Standards Handbook*, for additional information.

A.3.3.51 Mesh Size. Table A.3.3.51 provides mesh sizes.

Table A.3.3.51 Mesh Designations

U.S. 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

A.3.3.52 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.

A.3.3.52.2 Combustible Metal. See A.1.1.3 for further information on determining the characteristics of metals.

A.3.3.52.3 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 chapter. The requirements have not changed. See 1.1.3 for additional guidance for alloys.

A.3.3.52.5 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, 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; water, cleaning agents and/or cutting oils. Metal alloys, organometallics, 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.

A.3.3.53 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.*

The MEC is sometimes incorrectly referred to as the lower flammable limit (LFL) or lower explosive limit (LEL). Dusts have no upper explosive concentration.

Δ **A.3.3.54 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. [**652,** 2019]

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. [**654,** 2020]

To characterize electronic or electrical equipment discharge ignition hazards, it is recommended that the ASTM E2019 test be conducted with inductance.

A.3.3.56 Nanometal Powder. Although nanomaterials are usually defined as particles smaller than 100 nanometers (0.1 μm), larger particulates with diameters of almost 500 nanometers (0.5μm) 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).

A.3.3.57 Noncombustible. Materials reported as noncombustible, where tested in accordance with ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* are considered noncombustible materials.

A.3.3.60 Pneumatic Conveying System. Pneumatic conveying systems include a wide range of equipment systems utilizing air or other gases to transport solid particles from one point to another. A typical system comprises the following:

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

[**652,** 2019]

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. [**652,** 2019]

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. [**652,** 2019]

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. [**652,** 2019]

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 are necessary, including the use of qualified design engineers and equipment system vendors.

A.3.3.63.1 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.

A.3.3.63.3 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 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 (microns) (200 mesh).

A.3.3.63.4 Combustible Metal Powder. See NFPA 499 or NFPA 497 for information on explosibility parameters of combustible dusts.

A.3.3.64 Powder Production Plant. Facilities or buildings in which powder or combustible dust is produced incidentally to operations are not considered powder production plants.

A.3.3.67 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.

A.3.3.69.1 Magnesium Ribbon. It should be considered a powder for storage.

A.3.3.70 Risk Assessment. A risk assessment is a process that performs the following:

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

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

N **A.3.3.74 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. [**652,** 2019]

N **A.3.3.74.1 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. [**652,** 2019]

N **A.3.3.74.2 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. [**652,** 2019]

A.3.3.76 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.

A.3.3.82 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 (SF_6) and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern.

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

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

[**652:**A.4.1]

A.4.2.1.1 Given the fast-acting nature of flash fire, deflagration, and explosions, the stated life safety objective recognizes the difficulty, if not the impossibility, of protecting occupants in the immediate proximity of the ignition. Thus, the stated objective is to protect occupants not in the immediate proximity of ignition. However, all available practices should be employed to ensure the safety of all persons both near and far from the ignition. An example of this might be the standard's prescriptive exception relative to the less than 8 ft^3 (0.2 m^3) air-material separator not requiring protection; however, the intent of the objective is to consider the effect of deflagration to occupants in the immediate area of the small air-material separator and mitigate this hazard if possible. Likewise, the standard has not defined "immediate proximity" in that this could mean within just feet of the hazard or within the same building or structure and leaves that judgment to the user. The intent of the objective is to employ all available and reasonable protection, techniques, and practices to protect all occupants understanding that it might not always be achievable. [**652:**A.4.2.1.1]

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. [**652:**A.4.2.2]

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. [**652:**A.4.2.2]

A.4.2.3 Adjacent compartments share a common enclosure surface (e.g., wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion. [**652:**A.4.2.3]

• **A.4.2.4** Usually, a facility or process system is designed using the prescriptive criteria until a prescribed solution is found to be infeasible or impracticable. Then the designer can use the performance-based option to develop a design, addressing the full range of fire and explosion scenarios and the impact on other prescribed design features. Consequently, facilities are usually designed not by using performance-based design methods for all facets of the facility but rather by using a mixture of both design approaches as needed. [**652:**A.4.2.4]

A.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.5.2.5 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. 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 variations 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.5.3 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.5.3.1 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.5.3.2 See Figure A.5.3.2 for typical basic material characterization. The particle size distribution should be characterized by the DV50 and DV10 values.

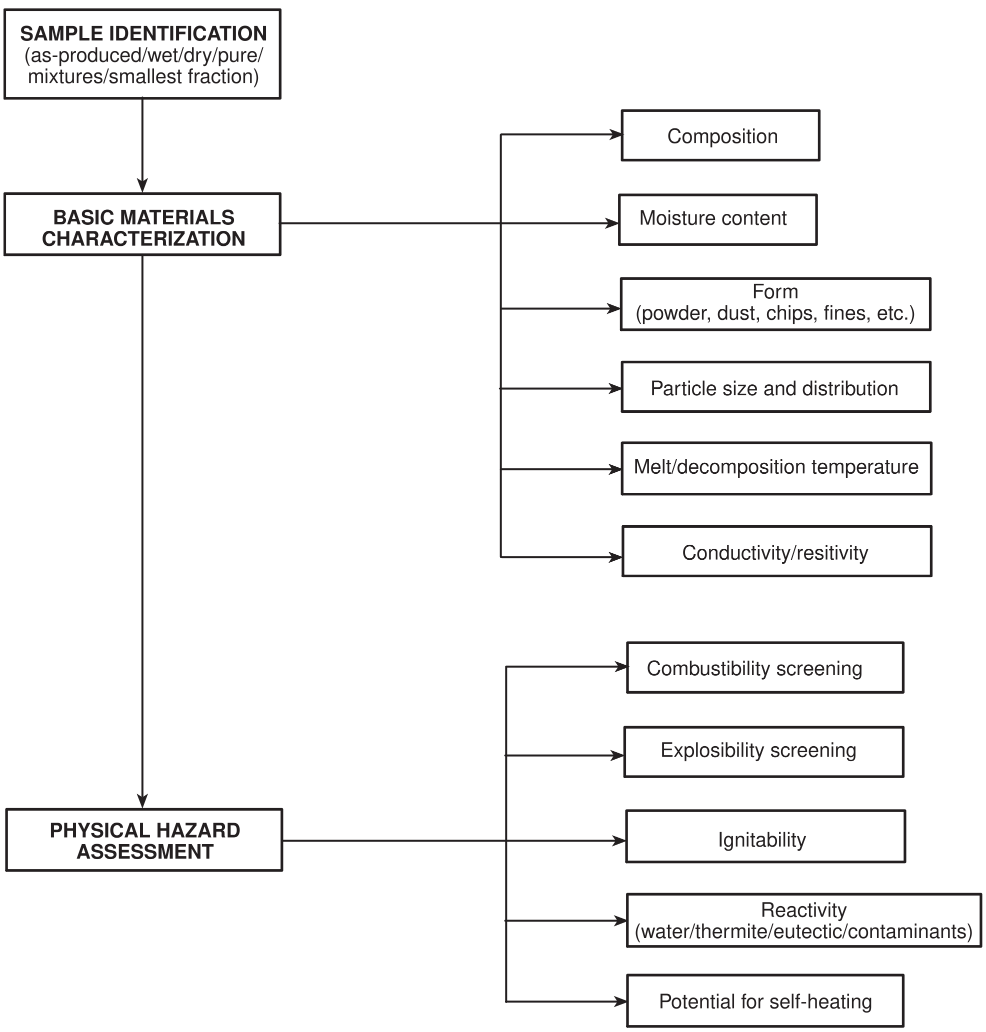

FIGURE A.5.3.2 Examples of Basic Materials Characterization.

A.5.4.1 This preliminary screening test used to demonstrate fire risk is the basis for the regulations governing the transport of dangerous goods for United Nations (UN) regulations, 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.5.4.4 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. Hazard analysis should be conducted to determine the extent to which the requirements of this document are applicable. It is recommended for general safety that the full requirements be met.

If the results of the screening test show propagation of the powder train, the material in the specific form should be considered a limited-combustible material and full compliance with the requirements of this document 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, hazard 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 NFPA 484. 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.5.4.5 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.5.4.5.

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 mm^2 (0.16 $in.^2$). In the case of a moisture-sensitive substance, the test must be carried out as quickly as possible after its removal from the container.

Test conditions are as follows:

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

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

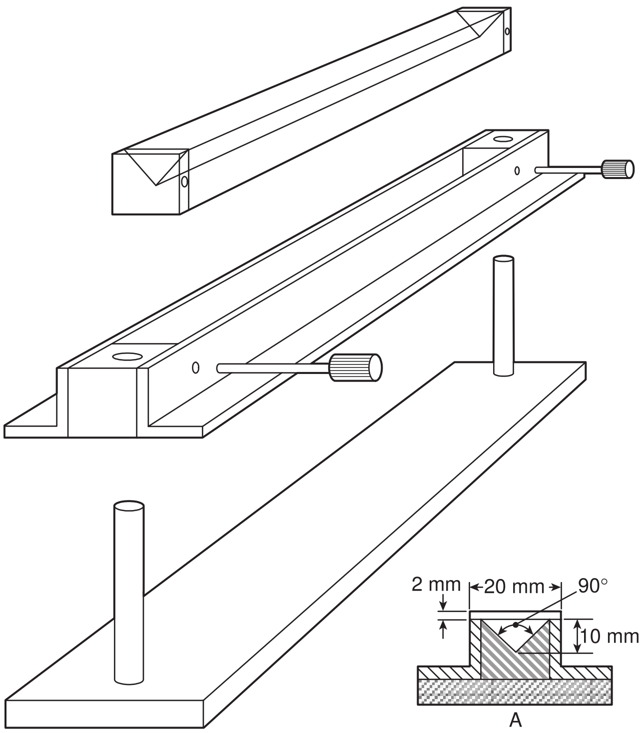

FIGURE A.5.4.5 Fixture for Preparation of Sample for Burning Rate Test.

A.5.4.5.1 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.5.5.1 Table A.5.5.1 gives a small sample of published ignition and explosion data on various sizes of aluminum powders.

N **A.5.5.1.1** 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.5.5.1.2 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.5.5.2 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 (≥1 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.1.1.3(a).]*

A.5.5.3 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.

Δ A.5.5.4 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.

Table A.5.5.1 Atomized Aluminum Particle Ignition and Explosion Data

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

For U.S. conversions: 1 m^2/g = 4884 ft^2/lb; 1 g/m^2 = 0.000062 lb/ft^2; 1 bar/sec = 14.5 psi/sec; 1 bar·m/sec = 0.226 psi·ft/sec.
BET: surface area per unit mass; MEC: minimum explosible concentration; MIE: minimum ignition energy; LOC: limiting oxygen (O_2) concentration.
Notes:
(1) The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.
(2) Data for each characteristic were obtained using the following ASTM methods: MEC: ASTM E1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*; MIE: ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*; maximum pressure rise (P_{max}), maximum pressure rise rate (dP/dt), and deflagration index (K_{St}): ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*; LOC: ASTM E2079, *Standard Test Methods for Limiting Oxygen (Oxidant) Concentration in Gases and Vapors.*
(3) Particle size data represent the d_{50} measurement determined by the laser light–scattering technique.
(4) Test results represent only the characteristics of those samples tested and should not be considered to be universally applicable. Users are encouraged to test samples of powders obtained from their individual process.
(5) The determination of explosibility parameters (i.e., P_{max}, LOC, K_{St}) for nanometals should be conducted with representative nanometal samples, because the values of some explosibility parameters can be significantly different than the corresponding values measured with micrometer-sized samples. In the case of many nanometals, the ASTM E1226 test methods to determine explosibility parameters require modification to prevent pre-ignition during compressed air injection into the test vessel. *(See Bouillard 2010 and Boilard 2013.)*

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 m^3. Materials are classified according to the *St* class system in Table A.5.5.4. 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, *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.5.6.1 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.5.6.2 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
  (b) Particle agglomeration influences including morphology and moisture content

A.5.7 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 an explosion pressure ratio greater than two, the test material should be considered to have a flash fire potential.

Table A.5.5.4 Explosive Energy Classification

St Class	K_{St} (bar-m/sec^{-1})
St 1	>0–200
St 2	201–300
St 3	>300

A.5.8 Many organometallic compounds — also referred to as metal organics — are pyrophoric, react violently with water, and burn with characteristics similar to combustible metals. Guidelines for safe handling of these materials are available from organometallic compound manufacturers such as www.fmclithium.com/portals/fmclithium/.../fmc_spclty-cat_web.pdf and https://www.akzonobel.com/polymer/safety/organometallics/. 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.

N **A.6.1.2** The SFPE *Guidelines for Peer Review in the Fire Protection Design Process* provides an example of how to conduct a peer review for a performance-based fire safety design.

A.6.1.3 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.

N **A.6.1.3.2** For traditional surface fire modeling, the 2011 edition of the SFPE *Guidelines for Substantiating a Fire Model for a Given Application* provides guidance on the documentation needed to select a fire model, as well as guidance on how to ensure a selected model is properly verified and validated. In the case of other types of combustible dust hazard phenomena, such as flash fires and dust explosions, there are other models that also require documentation of assumptions, methodology, and validation.

A.6.1.4 Relevant aspects that could require a re-evaluation include, but are not limited to, changes to the following:

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

Intentional changes to process materials, technology, equipment, procedures, and facilities are controlled by section by sections pertaining to management of change.

A.6.2.3 Other stakeholders could also have mission continuity goals that will necessitate more stringent objectives as well as more specific and demanding performance criteria. The protection of property beyond maintaining structural integrity long enough to escape is actually a mission continuity objective. The mission continuity objective encompasses the survival of both real property, such as the building, and the production equipment and inventory beyond the extinguishment of the fire. Traditionally, property protection objectives have addressed the impact of the fire on structural elements of a building as well as the equipment and contents inside a building. Mission continuity is concerned with the ability of a structure to perform its intended functions and with how that affects the structure's tenants. It often addresses post-fire smoke contamination, cleanup, replacement of damaged equipment or raw materials, and so forth.

A.6.2.4.1 Adjacent compartments are those sharing a common enclosure surface (wall, ceiling, floor) with the compartment of fire or explosion origin. The intent is to prevent the collapse of the structure during the fire or explosion.

A.6.3.5(3) Deflagration vent operation does not constitute rupture of the equipment.

A.6.4 The risk evaluation conducted according to Section 5.7 might be useful in identifying the design scenarios for Section 6.4.

The fire and explosion scenarios defined in Section 6.4 assume the presence of an ignition source, even those scenarios limited by administrative controls (such as a hot work permit program). It is the responsibility of the design professional to document any scenario that has been excluded on the basis of the absence of an ignition source.

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

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

A.7.1 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.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.7.2.1.3 One method by which the requirement in 7.2.1.3 can be satisfied is with a hazard analysis conducted in accordance with the methods outlined in *Guidelines for Hazard Evaluation Procedures*. To determine if a dust deflagration hazard exists, see Figure 5.5.1.

A.7.2.2.1 NFPA standards rely on the determination of "where an explosion hazard or deflagration hazard exists." There are other physical and health hazards to consider such as toxicity, reactivity with water, and so forth that can be considered when conducting a DHA. The DHA should consider the four conditions that are required for a deflagration:

(1) A combustible particulate solid of sufficiently small particle size to deflagrate
(2) A combustible particulate solid suspended in air to deflagrate (or other oxidizing medium)
(3) A combustion particulate solid suspension of sufficiently high concentration to deflagrate
(4) A competent igniter applied to the suspension of combustible particulate solids where the concentration is sufficient for flame propagation. [**652:**A.7.2.1]

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

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

[**652:**A.7.2.1]

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

(1) Acoustic impulse waves of the initial, primary, deflagration
(2) Entrainment by deflagration pressure front

[**652:**A.7.2.1]

The majority of the property damage and personnel injury is due to the fugitive dust accumulations within the building or process compartment. The elimination of accumulated fugitive dust is CRITICAL and the single most important criterion for a safe workplace. [**652:**A.7.2.1]

A.7.2.2.2 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 metals. Typically, a team performs a DHA. For some processes this team can be as few as two persons, or for larger and more complex processes, the team might require more than two persons. This team is made of a variety of persons whose background and expertise can include the following:

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

[**652:**A.7.2.2]

The individuals involved in the DHA could include facility operators, engineers, owners, equipment manufacturers, or consultants. [**652:**A.7.2.2]

A.7.2.3.1(2)(b) The hazard management document for all the areas of the process or facility compartment determined to be combustible dust hazards should include, but not be limited to, the following:

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

[**652:**A.7.3.1(2)(b)]

Paragraph 7.2.3.1 outlines the minimum steps of a dust hazards analysis. [**652:**A.7.3.1(2)(b)]

A.7.2.3.3.1 This includes the process systems and ancillary equipment such as dust collection systems. Where multiple compartments present essentially the same hazard, a single evaluation might be appropriate. [**652:**A.7.3.3.1]

A.7.2.3.3.3 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. The process and process equipment will often determine which option is most appropriate. *(See Annex B of NFPA 652 for an example of a process hazard analysis.)*

A.7.2.3.4.2 Each and every facility compartment containing combustible metal 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.

A.7.3.2.2 See A.7.2.2.2.

Δ **A.7.3.3.1(2)(b)** See A.7.2.3.1(2)(b).

A.7.3.3.3.1 See A.7.2.3.3.1.

A.7.3.3.3.3 See A.7.2.3.3.1.

N **A.8.2** See ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems.* [**652:**A.8.2]

A.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.

N **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

[**652:**A.8.5.1]

N **A.8.5.2** The hot work area specified in NFPA 51B is 11 m (35 ft). [**652:**A.8.5.2]

A.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 U.S. Chemical Safety Board’s case study report on the Hoeganaes Corporation's fatal flash fires.)*

A.8.6.1.2 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.8.6.2.3 Performance requirements described in ASTM F1002 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.

Δ **A.8.6.3.1** NFPA 2113 describes requirements and criteria for wearing garments made and tested in accord with NFPA 2112.

A.8.6.3.2 Testing has shown that the 84 kW/m^2 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 fire-fighting application in NFPA 1971 and for arc flash protection in ASTM F2621, *Standard Practice for Determining Response Characteristics and Design Integrity of Arc Rated Finished 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.8.6.3.6 Heat-resistant fabrics include, but are not limited to, Kevlar, Nomex, and heavy leather.

A.8.6.3.7 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. Where static-dissipative safety shoes are used, a testing program to confirm that the shoes are static-dissipating should be in place.

A.8.6.4.4 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.8.6.4.5.1 Burning combustible metals will burn through material used in the construction of most fire fighter 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 fire fighters 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 fire fighter's view to an unacceptable degree.

N **A.8.9.2** Qualified contractors should have proper credentials, which include applicable American Society of Mechanical Engineers (ASME) stamps, professional licenses, and so forth. [**652:**A.8.9.2]

N **A.8.9.3** It is suggested that annual meetings be conducted with regular contractors to review the facility's safe work practices and policies. Some points to cover include to whom the contractors would report at the facility, who at the facility can authorize hot work or fire protection impairments, and smoking and nonsmoking areas. The owner/operator does not necessarily need to provide the training to the contractor. [**652:**A.8.9.3]

N **A.8.9.3.3** In addition to the combustible dust fire and explosion hazards, contractors should also be made aware of other potential process and occupational hazards. There can be combustible materials other than combustible dusts in the equipment or immediate vicinity where contractors might be working. Combustion of dusts can generate toxic products, and some combustible dusts are acutely toxic. [**652:**A.8.9.3.3]

N **A.8.11** To thoroughly assess the risks, analyze the incident, and take any corrective steps necessary, investigations should be conducted promptly based on the nature of the incident and in coordination with the AHJ (as applicable). [**652:**A.8.11]

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. [**652:**A.8.11]

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. [**652:**A.8.11]

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. [**652:**A.8.11]

A system should be established to promptly address and resolve the incident report findings and recommendations. [**652:**A.8.11]

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. [**652:**A.8.11]

Reports produced by external investigation agencies should be acted upon in the same manner as internal investigations. [**652:**A.8.11]

Incident investigation reports should be made available to affected employees and their representatives at no cost. [**652:**A.8.11]

N **A.8.11.1** Events where there are injuries, equipment damage, or significant business interruption are subject to investigation. [**652:**A.8.11.1]

In addition to investigation of fires and explosions, it is also a good practice to investigate near misses (events that could have resulted in fires or explosions under different circumstances) and all activations of active fire and explosion mitigation systems. It is important to educate facility personnel on the concept of what a near miss is and to clearly communicate their responsibility for reporting both incidents and near misses. [**652:**A.8.11.1]

Near-miss events often indicate an underlying problem that should be corrected. See NFPA 654 for additional information. Barriers to reporting should be removed, as described in ANSI/AIHA Z10, *Occupational Health and Safety Management Systems*. Investigations should include workers and their representatives, as appropriate. [**652:**A.8.11.1]

N **A.8.11.4** The term *affected personnel* is intended to include members of employee organizations such as safety committees and employee representatives of various types. [**652:**A.8.11.4]

Δ **A.8.12.1** It is essential to have thorough written documentation, as the slightest changes to procedures, processes, resources, staffing, and equipment, including equipment from suppliers, can have a dramatic impact on the overall hazard analysis. Change includes something as benign as process materials sourcing from a different manufacturer, the same raw material manufacturer using new methods to produce the product, or changes in formulation. These changes from a supplier's end can impact the characteristics of the processes and materials. [**652:**A.8.12.1]

Individuals involved should include those involved in the process such as maintenance, engineering, and purchasing personnel, and all others as deemed necessary. Staffing and job tasks are not intended for shift changes, but for overall staff and their representative tasks. For reference, see the documentation form in ANSI/AIHA Z10, *Occupational Health and Safety Management Systems*.

The following changes in material or process should warrant a management of change review per Section 8.12, and new samples should be collected and analyzed:

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

[**652:**A.8.12.1]

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N **A.8.12.2(1)** The proposed change and why it is needed should be described. It should include sufficient technical information to facilitate review by the approvers, address adverse effects that could occur, and describe how such effects would be mitigated by the proposed change. [**652:**A.8.12.2(1)]

N **A.8.12.2(2)** Some fire and explosion protection systems introduce additional hazards into the process environment. These hazards can include, but are not limited to, energy in suppression canisters, asphyxiation hazards from inert gases, and mechanical laceration/amputation hazards from explosion isolation systems. While these are not fire or explosion hazards, they should be addressed as part of the management of change review per this document so that appropriate controls can be applied. [**652:**A.8.12.2(2)]

N **A.8.12.3** While implementation of the management of change procedure is not required for replacement in kind, it is critical that only qualified personnel are the ones who determine if the replacement is "in kind." These qualified personnel should be intimately familiar with the items listed in 8.12.2, as well as the broad scope of hazards associated with the particular process. [**652:**A.8.12.3]

Replacement "in kind" for raw materials. Care must be taken when substituting raw materials. There have been cases where a seemingly equivalent material substitution resulted in a large change in the process hazard. Not all safety properties of a material are characterized in, for example, an MSDS. Chemical composition might be identical, but quite different static ignition hazards due to bulk resistivity and charge relaxation rate can appreciably increase the hazard. Flowability differences can affect the hazard probability too. Differences in natural raw materials are generally less of a concern than manufactured materials in this regard. [**652:**A.8.12.3]

N **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. [**652:**A.8.13]

N **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. [**652:**A.8.13.1(3)]

N **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. [**652:**A.8.13.1(5)]

N **A.8.13.1(6)** Management of change documents should be retained until the changes are incorporated into the next dust hazards analysis. [**652:**A.8.13.1(6)]

N **A.8.13.1(8)** Contractor records typically include information such as the contract documentation with scope of work and necessary insurance coverage, the contractor's safety programs, records demonstrating the contractor's safety performance, qualifications and certifications necessary for the work to be done, periodic evaluations of the contractor's work performance, and records demonstrating that the employees of the contractor have been trained to safely perform the assigned work. [**652:**A.8.13.1(8)]

N **A.8.15** Effective employee participation is an essential element of the Occupational Health and Safety Management System (OHSMS) to achieve continuous improvement in risk reduction, as described in ANSI/AIHA Z10-2012, *Occupational Health and Safety Management Systems*. The OHSMS ensures that employees and their authorized representatives are involved, informed, and trained on all aspects of health associated with their work, including emergency arrangements. Employee participation includes items such as, but not limited to, the following:

(1) Involving employees and their authorized representatives, where they exist, in establishing, maintaining, and evaluating the OSHMS
(2) An occupational health and safety committee

(3) Access to safety and health information
(4) Risk assessment, implementation, and review of risk control measures
(5) Incident and near-miss investigations
(6) Inspections and audits
(7) Reporting unsafe conditions, tools, equipment, and practices
(8) Mentoring of new employees, apprentices, and for on-site orientation
(9) Identifying hazards with strong emphasis on high-risk jobs and the application of the hierarchy of controls
(10) In accordance with established and maintained procedures, appropriate arrangements to ensure that concerns, ideas, and input that employees and their representatives share are received, considered, and responded to
(11) Employees removing themselves from work situations that they have reasonable justification to believe present an imminent and serious danger to their safety or health

[**652:**A.8.15]

Employees who justifiably take those actions by notifying their supervisor should be protected from discrimination by removing those barriers as outlined in the OSHMS. [**652:**A.8.15]

Where this standard and annex refer to employees and their representatives (where representatives exist), the intention is that they should be consulted as the primary means to achieve appropriate participation in the development and implementation of all aspects of the OHSMS. In some instances, it might be appropriate to involve all employees and all representatives. [**652:**A.8.15]

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. [**652:**A.8.15]

Employees and their representatives need to be trained about how the OHSMS works and to evaluate it periodically to determine whether improvements need to be made. The information needs to be presented in a form and language that employees and their representatives easily understand. *(See also A.8.11.4.)* [**652:**A.8.15]

N **A.9.1** Facility owners should consider inherently safer options when designing or modifying processes that handle combustible particulate solids. Inherently safer design focuses on eliminating or reducing hazards of a process through minimization, substitution, moderation, and simplification, without the addition of procedures or engineered protection systems. The concepts of inherently safer design are described generally in *Inherently Safer Chemical Processes, A Life Cycle Approach,* published by the Center for Chemical Process Safety, and more specifically for combustible dust in "Application of inherent safety principles to dust explosion prevention and mitigation," published in *Process Safety and Environmental Protection.* [**652:**A.9.1]

Inherently safer design concepts should be used when evaluating options for the design of new processes. When applied early in the design phase of a project, it is often possible to reduce the overall cost of explosion protection by reducing the number of vessels requiring protection or allowing simple, low-cost options such as explosion venting to be used. These concepts can also be applied to facility design to reduce the migration and accumulation of fugitive dust emissions through HVAC and exhaust system design and by minimizing inaccessible horizontal surfaces where dust can accumulate. [**652:**A.9.1]

Consideration for inherently safer design options should be included in the dust hazards analysis where explosion hazards are identified. The inherently safer design concepts can be used to identify alternative solutions where hazards can be eliminated rather than controlled. [**652:**A.9.1]

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. [**652:**A.9.1]

N **A.9.2.2** It is preferable for buildings that handle combustible dust to be of either Type I or II construction, as defined by NFPA 220. [**652:**A.9.2.2]

N **A.9.2.3.1** Chapter 7 provides the process to determine where and whether a dust deflagration hazard exists. Section 9.2 is not intended to cover process equipment such as bins and silos. [**652:**A.9.2.3.1]

N **A.9.2.3.2** An enclosed means of egress is intended to be an exit separated from other parts of the building or building compartment as used in NFPA *101*. Examples include exit stair enclosures and horizontal exit passageways. [**652:**A.9.2.3.2]

N **A.9.2.5.1** To the extent feasible and practical from a cost and sanitation standpoint, horizontal surfaces should be minimized to prevent accumulation of dust. Horizontal surfaces that can benefit from a sloped cover include girders, beams, ledges, and equipment tops. Overhead steel I-beams and similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. The additional weight of the box enclosures should be considered in the structural design. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning. One option based on clean design concepts is to construct the building walls so that the structural supports, electrical conduit, and so forth are on the exterior side of the building walls; therefore, the interior building compartment walls are smooth and less likely to collect fugitive dust. [**652:**A.9.2.5.1]

N **A.9.2.5.3** The space above suspended ceilings is an example of a space that is difficult to access for routine housekeeping. Periodic inspection of such spaces is necessary to ensure accumulations do not result in a deflagration hazard area. [**652:**A.9.2.5.3]

Δ **A.9.2.6.3.1** A building could be considered as a single dust flash-fire hazard area, or as a collection of smaller, separated combustible dust hazard areas. When the owner/operator chooses to consider the building as a single area, then the hazard analysis should consider the entire building floor area and the considerations for mitigation apply to the entire building. Where the combustible dust hazard areas are sufficiently distant to assert separation and the owner/operator chooses to consider each hazard area separately, the hazard analysis should consider each separated area and the considerations for mitigation should be applied to each area independently. Due consideration should be given to overhead dust accumulations, such as on beams or ductwork, which would negate the use of separation to limit combustible dust hazard areas. If the separation option is chosen, a building floor plan, showing the boundaries considered, should be maintained to support housekeeping plans. [**652:**A.9.2.6.3.1]

A.9.2.6.3.2 Separation distance is the distance between the outer perimeter of a primary dust accumulation area and the outer perimeter of a second dust accumulation area. Separation distance evaluations should include the area and volume of the primary dust accumulation area as well as the building or room configuration. [**652:**A.9.2.6.3.2]

N **A.9.2.6.3.5** The assertion of separation must recognize the dust accumulation on all surfaces in the intervening distance, including floors, beam flanges, piping, ductwork, equipment, suspended ceilings, light fixtures, and walls. Process equipment or ductwork containing dust can also provide a connecting conduit for propagation between accumulation areas. In order to prevent flame propagation across the separation distance, the dust accumulation should be very low. The National Grain and Feed Association study, *Dust Explosion Propagation in Simulated Grain Conveyor Galleries,* has shown that a layer as thin as $\frac{1}{100}$ in. is sufficient to propagate flame in a limited expansion connection, such as an exhaust duct or a hallway. In the subject study, the flame propagated for at least 24.4 m (80 ft) in a gallery 2.4 m (8 ft) tall by 2.4 m (8 ft) wide. [**652:**A.9.2.6.3.5]

N **A.9.2.6.4.2** Detachment distance is the radial distance between nearest points of two unconnected adjacent buildings. [**652:**A.9.2.6.4.2]

A.9.2.7 These facility design requirements are in addition to those in Sections 16.2, 17.2, and 18.2. Consideration should be given to automatic fire detection systems in facilities handling metals in combustible form.

A.9.2.7.3.2.1 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.

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N **Table A.9.1 Examples of Inherently Safer Design**

Principle	Description	Examples
Minimization	Use smaller quantities of hazardous materials when the use of such materials cannot be avoided. Perform a hazardous procedure as few times as possible when the procedure is unavoidable.	Use cutting methods that produce less combustible dust. Reduce the size and number of process vessels that handle combustible dust and produce dust clouds. Design facilities to minimize horizontal surfaces where dust can accumulate.
Substitution	Replace a substance with a less hazardous material (i.e., a completely new substance) or a processing route with one that does not involve hazardous material. Replace a hazardous procedure with one that is less hazardous.	Replace a powder raw material with a liquid formulation or one that is preblended with other noncombustible raw materials used in the process. Use granular or coarse particulate solids instead of dusts. Replace a bucket elevator with a dense phase conveying system. When conveying dry raw materials into a liquid mix vessel, use a liquid eductor to combine the dry and wet ingredients and convey them together.
Moderation	Use hazardous materials in their least hazardous forms (i.e., the same substance but in a safer formulation) or identify processing options that involve less severe processing conditions.	Use powdered materials having a larger particle size distribution or higher moisture content. Perform size reduction processes on moist material prior to drying. Use processing methods that minimize fine dust generation. Change the order of addition of raw materials. For example, add a combustible dust to a vessel prior to adding a flammable solvent.
Simplification	Design processes, processing equipment, and procedures to eliminate opportunities for errors by eliminating excessive use of add-on safety features and protective devices.	Where operator grounding is required, use static dissipative footwear and flooring rather than leg or wrist straps that must be attached prior to performing an operation. Locate dust collectors outdoors in unoccupied areas, where explosion vents can be used instead of more complex protection systems. Perform milling and drying in one step vs. a two-step drying then milling process.

[**652:**Table A.9.1]

A.9.2.7.3.3.7 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.9.2.7.4 A ridged or peaked roof that allows for natural ventilation of hydrogen is recommended.

A.9.2.7.5.1 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 explosion 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.

Δ **A.9.2.7.5.3** For further information, see NFPA 68.

A.9.2.7.5.6 For information on deflagration venting, see NFPA 68.

A.9.2.7.6 For information on static electricity, see NFPA 77.

A.9.2.8.3.3 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.

N **A.9.3.1** A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with only some, or possibly none, of the prescribed protective measures. More specifically, while ignition source control without consideration of the potential consequences is generally not an accepted primary means of explosion protection, a risk assessment (which by definition requires consideration of the consequences) could determine that ignition source control provides an acceptable level of safety. [**652:**A.9.3.1]

N **A.9.3.9.1.2** Shipping containers can pose a deflagration hazard; however, deflagration protection measures for these units are not always practical. Consideration should be given to deflagration hazards when electing to omit deflagration protection. [**652:**A.9.3.9.1.2]

N **A.9.3.9.2** Historically, NFPA 654 has required that fixed bulk storage enclosures be constructed of noncombustible materials, which usually meant a metallic material. However, there are some particulates that represent a serious corrosion threat or where contamination from the materials of construction introduces product quality issues, therefore nonmetallic construction is required. The materials of construction for a bulk storage enclosure should not increase the fire protection challenge. [**652:**A.9.3.9.2]

N **A.9.3.9.3.2(2)** Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practicable. Consideration should be given to explosion hazards when electing to omit protection. [**652:**A.9.3.9.3.2(2)]

N **A.9.3.9.4** Horizontal projections can have the tops sharply sloped to minimize the deposit of dust thereon. Efforts should be made to minimize the amount of surfaces where dust can accumulate. [**652:**A.9.3.9.4]

N **A.9.3.10** Size reduction machinery includes equipment such as mills, grinders, and pulverizers. [**652:**A.9.3.10]

N **A.9.3.11** Particle separation devices include screens, sieves, aspirators, pneumatic separators, sifters, and similar devices. [**652:**A.9.3.11]

N **A.9.3.12.2.4** High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust. [**652:**A.9.3.12.2.4]

N **A.9.3.14** It is recommended that bucket elevators be located outside of buildings whenever practicable. [**652:**A.9.3.14]

N **A.9.3.14.4.1** Belt alignment monitoring devices are recommended for all elevator legs. Bearing monitoring systems are recommended for head, tail, and bend (knee) pulley bearings on elevator legs. [**652:**A.9.3.14.4.1]

N **A.9.3.14.4.2** Where conductive buckets are used on nonconductive belts, bonding and grounding should be considered to reduce the hazards of static electricity accumulation. *(See NFPA 77 for more information.)* ISO 284, *Conveyor Belts — Electrical Conductivity — Specification and Test Method,* or DIN 22104, *Antistatic Conveyor Belts — Specification and Method of Test,* can be used to evaluate conductivity. ASTM D378, *Standard Test Methods for Rubber (Elastomeric) Conveyor Belting, Flat Type,* or ISO 340, *Conveyor Belts — Laboratory scale flammability characteristics — Requirements and test method,* are standards that can be used to evaluate fire resistance. [**652:**A.9.3.14.4.2]

N **A.9.3.14.4.4** Where it is desired to prevent propagation of an explosion from the elevator leg to another part of the facility, an explosion isolation system should be provided at the head, boot, or both locations. [**652:**A.9.3.14.4.4]

N **A.9.3.14.5.1** The motor selected should not be larger than the smallest standard motor capable of meeting this requirement. [**652:**A.9.3.14.5.1]

N **A.9.3.15** Explosion protection should be provided when the risk is significant. Where coverings are provided on cleanout, inspection, or other openings, they should be designed to withstand the expected deflagration pressure. [**652:**A.9.3.15]

N **A.9.3.15.2.1** Methods by which this shutoff can be achieved include sensing overcurrent to the drive motor or high motor temperature. [**652:**A.9.3.15.2.1]

N **A.9.3.17** Dryers include tray, drum, rotary, fluidized bed, pneumatic, spray, ring, and vacuum types. Dryers and their operating controls should be designed, constructed, installed, and monitored so that required conditions of safety for operation of the air heater, the dryer, and the ventilation equipment are maintained. [**652:**A.9.3.17]

N **A.9.3.17.1.7** The maximum safe operating temperature of a dryer is a function of the time–temperature ignition characteristics of the particulate solid being dried as well as of the dryer type. For short time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature. [**652:**A.9.3.17.1.7]

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. [**652:**A.9.3.17.1.7]

The dust cloud ignition temperature can be determined by the method referenced in U.S. Bureau of Mines RI 8798, "Thermal and Electrical Ignitability of Dusts" (modified Godbert-Greenwald furnace, BAM furnace, or other methods). The dust layer ignition temperature can be determined by the U.S. Bureau of Mines test procedure given in Lazzara and Miron's report, "Hot Surface Ignition Temperatures of Dust Layers." [**652:**A.9.3.17.1.7]

N **A.9.4.1** It is not always possible or practical for existing facilities to be in compliance with the new provisions of a standard at the effective date of that standard. Therefore, "retroactivity" in 9.4.1 means that a plan should be established to achieve compliance within a reasonable time frame. [**652:**A.9.4.1]

N **A.9.4.2** A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. Where multiple protections are prescriptively required, a risk assessment could determine that an adequate level of safety can be achieved with only some, or possibly none, of the prescribed protective measures. More specifically, while ignition source control without consideration of the potential consequences is generally not an accepted primary means of explosion protection, a risk assessment (which by definition requires consideration of the consequences) could determine that ignition source control provides an acceptable level of safety. [**652:**A.9.4.2]

N **A.9.4.4.2** Consensus standard hot surface dust layer ignition temperature tests include ASTM E2021, *Standard Test Method for Hot-Surface Ignition Temperature of Dust Layers,* and IEC 61241-2-1, *Electrical Apparatus for Use in the Presence of Combustible Dust — Methods for Determining the Minimum Ignition Temperatures of Dust.* The dust layer thickness used in these tests is nominally 1.27 cm (0.5 in.). Thicker dust layers produce lower hot surface ignition temperatures. [**652:**A.9.4.4.2]

N **A.9.4.5.3** 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. [**652:**A.9.4.5.2]

Such equipment can include, but is not limited to, the following:

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

[**652:**A.9.4.5.2]

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. [**652:**A.9.4.5.2]

N **A.9.4.5.5** The risk assessment should include the potential for propagation of an explosion from an unmonitored unit. [**652:**A.9.4.5.4]

N **A.9.4.7** Several types of electrostatic discharges are capable of igniting combustible dusts and hybrid mixtures. The requirements in 9.4.7 are intended to protect against the following four types of discharge: Brush, cone (or bulking brush), propagating brush, and capacitive spark. [**652:**A.9.4.7]

Brush discharges occur when electrostatic charge accumulates on a nonconductive surface and is discharged to nearby conductor. These discharges have a maximum theoretical discharge energy of 3 mJ–5 mJ, which is sufficient to ignite most flammable vapors and gases. There are no records of brush discharges igniting combustible dusts outside of laboratory settings. In the first edition of this standard, a 3 mJ MIE limit was applied as a minimum criterion for the use of nonconductive system components. The intent of this criterion was to ensure that brush discharges were prevented when the MIE was less than the theoretical upper limit of brush discharge energy. However, even where combustible dusts have MIE values less than 3 mJ, the diffuse nature of a brush discharge makes it a less effective ignition source than the capacitive spark used for determining the MIE value. [**652:**A.9.4.7]

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. [**652:**A.9.4.7]

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. [**652:**A.9.4.7]

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. [**652:**A.9.4.7]

For more information on electrostatic discharges, refer to NFPA 77 and IEC TS 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, guidance.* [**652:**A.9.4.7]

A.9.4.7.1 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.9.4.7.1.1 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.9.4.7.1.1.2 Examples are gaskets between ductwork sections, and flexible hoses.

A.9.4.7.1.2 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.9.4.7.1.3 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.9.4.7.1.6 NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of noncombustible residues do not interfere with continuity.

A.9.4.7.1.6.2(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.9.4.7.1.6.2(2) Based on information found in *Avoiding Static Ignition Hazards in Chemical Operations*, the maximum reasonable discharge energy from a person is estimated to be approximately 25 mJ. Where the MIE of the dust cloud is greater than 30 mJ, personnel grounding provides no risk reduction. MIE is dependent on particle size, so it is important to determine the MIE value on the particle size distribution that is likely to remain airborne during the operation. Since large particles will quickly fall out of suspension, the sub-75 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.9.4.7.2.1 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.9.4.7.2.2 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.

N **A.9.4.7.3.2(1)** This requirement is intended to prevent ignition of hybrid mixtures or flammable gas/vapor atmospheres by brush discharges from nonconductive surfaces. [**652:**A.9.4.7.1.2(1)]

N **A.9.4.7.3.2(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. [**652:**A.9.4.7.1.2(2)]

N **A.9.4.7.3.2(3)** This requirement is intended to prevent ignition of combustible dusts by capacitive sparks from isolated process equipment. [**652:**A.9.4.7.1.2(3)]

N **A.9.4.7.3.2(4)** This requirement is intended to prevent ignition of combustible dusts by propagating brush discharges. Pneumatic conveying is an example of a process operation that can generate high surface charging. [**652:**A.9.4.7.1.2(4)]

N **A.9.4.7.3.3** 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. [**652:**A.9.4.7.1.3]

See Figure A.9.4.7.3.3 for illustrations of bonding and grounding principles. [**652:**A.9.4.7.1.3]

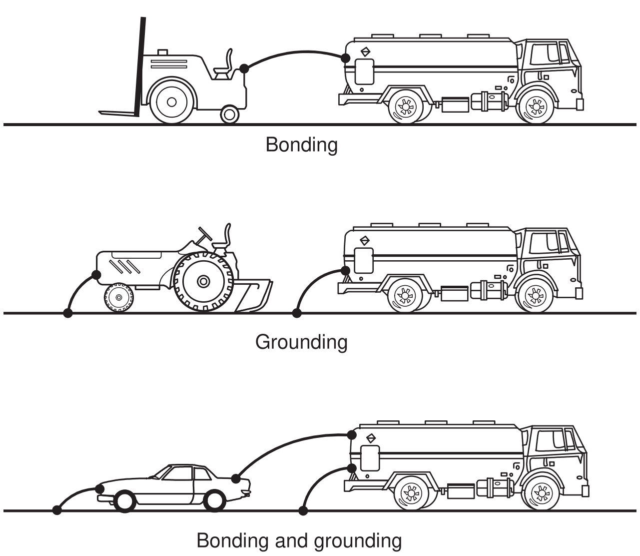
N **A.9.4.7.3.4** In order to properly specify a flexible connector for combustible dust service, it is necessary to know the end-to-end resistance. The end-to-end resistance is typically not specified by the suppliers of flexible connectors. This makes it necessary for the user to measure it. ISO 8031, *Rubber and plastics hoses and hose assemblies — Determination of electrical resistance and conductivity*, provides methods to determine the end-to-end resistance. For convenience, the following is a brief description of a similar procedure:

(1) It is preferred to measure the actual flexible connector to be used, but if it is too long for this to be practical, a shorter length (for example, 6 in. to 24 in.) can be used. The measured end-to-end resistance per unit length can then be multiplied by the total flexible connector length to get the overall flexible connector end-to-end resistance.

(2) The flexible connector should be placed on a nonconductive surface, such as a rigid sheet of PTFE, polyethylene, or polypropylene. It is important that neither the flexible connector or megohm meter metal connections are touched by the operator's bare skin during the measurement as this will short the circuit. In addition, the rigid polymer sheet and flexible connector should be dry during the measurement.

(3) The leads on a megohm meter should be contacted on the inside surface of the flexible connector at each end. This should be done at several points on the inside surface to ensure that a consistent reading is obtained. Care should be taken to make measurements at the greatest distance from any supporting wires in the flexible connector to avoid measuring the resistance across the wire. The readings should be taken at approximately 500 V.

[**652:**A.9.4.7.1.4]



N **FIGURE A.9.4.7.3.3 Bonding and Grounding. [652:Figure A.9.4.7.1.3]**

N **A.9.4.7.3.4.1** 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. [**652:**A.9.4.7.1.4.1]

N **A.9.4.7.3.4.3** Propagating brush discharges, which are generally considered to be the most energetic type of electrostatic discharge, do not produce discharge energies in excess of 2000 mJ. [**652:**A.9.4.7.1.4.3]

N **A.9.4.7.4.1** The limit on particulate discharge rates is due to concern about possible generation of charge accumulation during rapid transport and the subsequent potential for a bulking brush discharge. From Britton, Section 2-6.3.2 in *Avoiding Static Ignition Hazards in Chemical Operations*, the minimum size of a container for bulking brush discharges to occur has not been established, but is probably about 1 m^3.

This section presumes that there are sufficient fine, suspendable particulates in the material so that the head space of the vessel being filled is at or above the MEC during the filling operation. Fine particulates are typically less than 0.075 mm (200 mesh). [**652:**A.9.4.7.2.1]

N **A.9.4.7.4.1(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.)* [**652:**A.9.4.7.2.1(1)]

N **A.9.4.7.4.1(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. [**652:**A.9.4.7.2.1(2)]

N **A.9.4.7.4.2** The maximum electrostatic discharge energy from a bulking brush discharge energy is about 20 mJ *(see Britton, Avoiding Static Ignition Hazards in Chemical Operations).* [**652:**A.9.4.7.2.2]

N **A.9.4.7.4.2(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. [**652:**A.9.4.7.2.2(1)]

N **A.9.4.7.4.2(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. [**652:**A.9.4.7.2.2(2)]

N **A.9.4.7.4.3** 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). [**652:**A.9.4.7.2.3]

N **A.9.4.7.5** NFPA 77 provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of noncombustible residues do not interfere with continuity. [**652:**A.9.4.7.3]

N **A.9.4.7.5.1** The user should expect that activities such as pouring, unloading, and transferring dusts can lead to the development of an ignitible atmosphere above the settled material in the receiving vessel. [**652:**A.9.4.7.3.1]

Refer to NFPA 77 for recommendations for how to safely ground personnel. [**652:**A.9.4.7.3.1]

N **A.9.4.7.5.2(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. [**652:**A.9.4.7.3.2(2)]

N **A.9.4.7.6** 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).* [**652:**A.9.4.7.4]

N **A.9.4.7.6.2** 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. [**652:**A.9.4.7.4.1]

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. [**652:**A.9.4.7.4.1]

N **A.9.4.7.6.3** 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. [**652:**A.9.4.7.4.2]

N **A.9.4.7.6.3.2** For this application, conductive particulate solids typically are those materials having bulk resistivity less than 10^6 ohm-m. [**652:**A.9.4.7.4.2.2]

N **A.9.4.7.6.4** 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. [**652:**A.9.4.7.4.3]

N **A.9.4.7.6.5** 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. [**652:**A.9.4.7.4.4]

N **A.9.4.7.6.6** 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. [**652:**A.9.4.7.4.5]

N **A.9.4.7.6.6.1** Type D bags function by corona discharge. Metals or other conductive particulate solids could require additional precautions because, if the particulate is isolated and becomes charged, incendiary sparks could occur during rapid filling and emptying operations. IEC TS 60079-32-1 gives guidance on additional precautions that could be necessary. A risk assessment referencing IEC TS 60079-32-1 could be performed to support the use of Type D FIBCs for conductive particulate solids. [**652:**A.9.4.7.4.5.1]

N **A.9.4.7.6.7** Table A.9.4.7.6.7 and Figure A.9.4.7.6.7 provide guides for the selection and use of FIBCs based on the MIE of product contained in the FIBC and the nature of the atmosphere surrounding it. Inner liners for FIBCs are separated into three types. Note that the selection of the type of liner is critical to maintaining classification of the FIBC. Appropriate inner liner selection, where applicable, is addressed in IEC 61340-4-4. [**652:**A.9.4.7.4.6]

N **A.9.4.7.6.8** In special cases it might be necessary to use a type of FIBC that is not permitted for the intended application based on the requirements of 9.4.7.6. 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. [**652:**A.9.4.7.4.7]

N **A.9.4.7.7.1** Conductive containers are generally made from either metal or carbon-filled plastic having a volume resistivity less than 10^6 ohm-m. [**652:**A.9.4.7.5.1]

N **A.9.4.7.7.2** 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. [**652:**A.9.4.7.5.2]

N **Table A.9.4.7.6.7 Use of Different Types of FIBCs**

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

Notes:
(1) Additional precautions usually are necessary when a flammable gas or vapor atmosphere is present inside the FIBC, for example, in the case of solvent wet solids.
(2) Nonflammable atmosphere includes combustible particulate solids having a MIE greater than 1000 mJ.
(3) FIBC Types A, B, and D are not suitable for use with conductive combustible particulate solids.
[a]Measured in accordance with ASTM E2019, capacitive discharge circuit (no added inductance).
[b]Use of Type C and D is limited to Gas Groups C and D with MIE greater than or equal to 0.14 mJ.
[**652:**Table A.9.4.7.4.6]

N **A.9.4.8.1** Maintenance and repair activities that can release or lift combustible dust include banging or shaking dust laden equipment components, blowing off dust accumulations from the surface of equipment, and inadvertently spilling combustible powder from a container. An example of a production activity that can generate a dust cloud is transporting an open drum of particulate past an operating fan. The dust clouds generated in these activities can be entrained into the airflow feeding a burner flame or pilot flame within nearby equipment. [**652:**A.9.4.8.1]

N **A.9.4.9.2** Diesel-powered front-end loaders suitable for use in hazardous (classified) locations have not been commercially available.

N **A.9.4.10.1** The maximum safe operating temperature of a dryer is a function of the time–temperature ignition characteristics of the particulate solid being dried as well as of the dryer type. For short-time exposures of the material to the heating zone, the operating temperatures of the dryer can approach the dust cloud ignition temperature. [**652:**A.9.4.10.1]

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. [**652:**A.9.4.10.1]

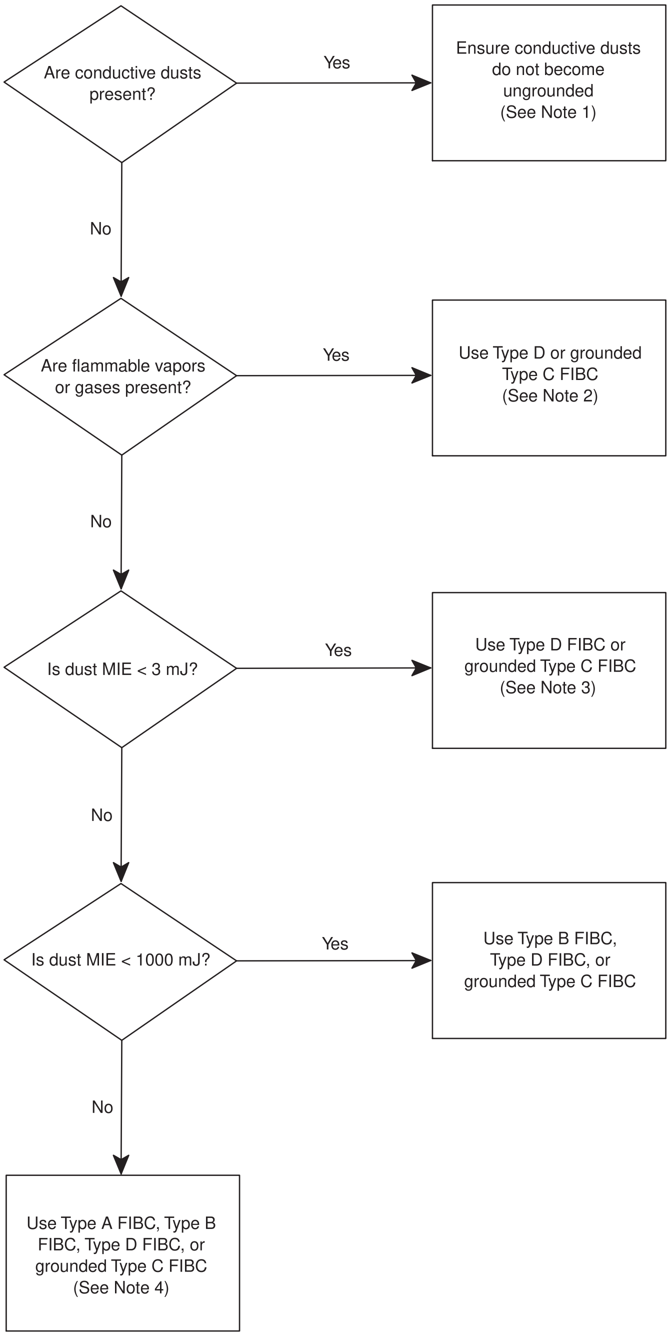
N **A.9.4.11.1** Particulate materials that are known to self heat under various circumstances include, but are not limited to, resinous sawdust, sewage sludge, powdered metals, wet agricultural materials, low rank coal, activated carbon charcoal, and bagasse. Tabulations of materials prone to self-heating can be found in the following references: *NFPA Fire Protection Handbook*; Bowes, *Self-Heating: Evaluating and Controlling the Hazards;* U.S. Department of Energy handbook, *Primer on Spontaneous Heating and Pyrophoricity;* and Babrauskas, *Ignition Handbook Database*. Test methods to assess the propensity for self-heating, and to determine critical storage pile sizes and time to self heat are also described in Bowes and Babrauskas. Methods of self-heating detection include temperature monitors within the pile or silo and carbon dioxide monitors in the silo. Self-heating management can be accomplished through timely processing of the affected particulate through the storage system before self-heating can become an issue. [**652:**A.9.4.11.1]

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. [**652:**A.9.4.11.1]

N **A.9.4.12.2** Methods that are commonly used to remove foreign material include the following:

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

[**652:**A.9.4.12.2]



Note 1: Conductive dusts can produce spark discharges if allowed to be isolated from ground. Grounded Type C FIBCs can provide adequate grounding, but some Type C FIBCs have internal coatings or liners that can allow conductive dusts to remain isolated. A risk assessment is recommended prior to handling conductive dusts in FIBCs.

Note 2: Do not use Type D FIBCs for flammable vapors/gases with MIE < 0.14 mJ.

Note 3: Type A or B FIBCs can allow cone discharges to occur across the full width of the FIBC, with an effective energy up to 3 mJ.

Note 4: Type A FIBCs have the potential to produce propagating brush discharges with effective energy of ~1000 mJ.

N **FIGURE A.9.4.7.6.7 FIBC Selection Decision Tree. [652:Figure A.9.4.7.4.6]**

N **A.9.4.12.4** In the case of size reduction equipment with continuous screened outlets, high speeds that can generate friction and impact sparks are considered to be tip speeds in excess of 10 m/sec. In the case of blenders and other completely enclosed equipment processing material in batches, high speeds are considered to be blade tip speeds in excess of 1 m/sec. [**652:**A.9.4.12.4]

A.9.4.13.1 The use of propellant-actuated tools presents several potential ignition source hazards, including the possibility of impact or friction spark generation, as well as the ignition of a propellant during use. All areas where such tools may be used should be thoroughly cleaned of any accumulation of metals in a combustible form and use should be strictly controlled under the facility hot work program.

A.9.4.15.1 Separation distances between a designated smoking area and areas where combustible metals are present are defined through a hazards analysis.

N **A.9.6.1** Other means to control fugitive dust emissions can include established housekeeping procedures where the fugitive emissions do not approach the MEC, and the housekeeping schedule does not allow settled dust accumulations to exceed the threshold housekeeping dust accumulation limit. [**652:**A.9.6.1]

N **A.9.6.3** These devices are used to continuously dislodge dust from hard-to-reach building surfaces such as roof structural members, lighting, and elevated ductwork. The fans used typically rotate through a 360 degree arc and oscillate up and down to keep dust from the surfaces within reach of the fan discharge. Large rooms require multiple fans for adequate coverage. [**652:**A.9.6.3]

These systems are most effective for facilities with high ceilings where light, easily entrained dusts or fibers are handled. [**652:**A.9.6.3]

N **A.9.6.3.8** These systems are intended to reduce the housekeeping burden on elevated surfaces. However, they do not remove dust from the facility. The material is simply relocated to lower surfaces where it is easier to clean using standard housekeeping procedures. These systems might increase the required housekeeping frequency on lower surfaces, and might increase the amount of dust carried into the building HVAC system. [**652:**A.9.6.3.8]

N **A.9.6.3.9** These systems should not be used where they can relocate dust into concealed spaces where the dust can accumulate and pose a deflagration hazard. [**652:**A.9.6.3.9]

N **A.9.7.3.1** Small containers can pose an explosion hazard; however, explosion protection measures for these units are not always practical. Consideration should be given to explosion hazards when electing to omit protection; 0.2 m^3 (8 ft^3) is roughly the size of a 208.2 L (55 gal) drum. [**652:**A.9.7.3.1]

N **A.9.7.3.3** 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.

N **A.9.7.4** A means to determine protection requirements should be based on a risk assessment, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. [**652:**A.9.7.4]

The requirement of 9.7.4.1 might not be applicable where all of the following conditions are met:

(1) The material being conveyed is not a metal dust, an ST-3 dust (K_{St} > 300 bar-m/sec), or a hybrid mixture.
(2) The connecting ductwork is smaller than 100 mm (4 in.) nominal diameter and greater than 5 m (15 ft) 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.

[**652:**A.9.7.4]

When managing the hazard of propagation via small duct, one can develop a performance equivalent alternative in accordance with Chapter 6. [**652:**A.9.7.4]

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 100 mm (4 in.) 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. [**652:**A.9.7.4]

FSA conducted flame propagation tests in a system comprising two interconnected and vented 1 m^3 (35 ft^3) vessels. Experiments were carried out with pipe diameters of 27 mm, 42 mm, and 82 mm (1.1 in., 1.6 in., and 3.2 in.), all diameters of less than 100 mm (4 in.). Corn starch (K_{St} = 200 bar-m/sec) and wheat flour (K_{St} ≈ 100 bar-m/sec) were used as fuels. Even with a small pipe diameter of 27 mm (1.1 in.) and with wheat flour (K_{St} ≈ 100 bar-m/sec) used as test dust, there was a flame propagation through a pipe length of at least 12 m (39 ft) in length. [**652:**A.9.7.4]

For interconnected vessels that are relatively close together, measures to reduce P_{red} for each interconnected vessel, taking into account that propagation could occur, would eliminate the need for isolation techniques. [**652:**A.9.7.4]

Dense phase pneumatic transfer [air velocities down near 183 m/min (600 fpm), 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 672 m/min to 1098 m/min (2200 fpm to 3600 fpm), 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 150 mm (5.9 in.) piping, even for dilute phase systems. However, recent testing has shown that propagation is more likely with dust concentrations in the lean region. Metal dusts are more likely to propagate deflagrations. For organic dusts, where small diameter pipes with dense phase transfer are utilized, the need for isolation techniques could be obviated if the hazard analysis is acceptable to the AHJ. [**652:**A.9.7.4]

Factors for evaluation of isolation between equipment and work areas include, among others, the anticipated P_{red} for the related process equipment, the diameter and length of the connecting air duct, the K_{St} of the dust, and the quantity of dust in the work area that can be entrained by a pressure pulse from a deflagration in the related process equipment. Zalosh and Greenfield (2014) have shown that the probability of propagation decreases exponentially with increasing values of the parameter $L/[(K_{St}–K_{min})(d – d_{min})]$, where L is the duct or pipe length between equipment, d is the duct or pipe diameter, K_{min} is the minimum K_{St} required for propagation in short pipes (configuration dependent), and d_{min} is the minimum diameter for propagation in short pipes (depends on P_{red}). For more information, see "Dust explosion propagation and isolation," by Jerome Taveau in the *Journal of Loss Prevention in the Process Industries.* [**652:**A.9.7.4]

See references in D.1.2.10 of NFPA 652 for additional information. [**652:**A.9.7.4]

N **A.9.8.2.2** Extreme care should be employed in the use of portable fire extinguishers in facilities where combustible dusts are present. The rapid flow of the extinguishing agent across or against accumulations of dust can produce a dust cloud. When a dust cloud is produced, there is always a deflagration hazard. In the case of a dust cloud produced as a result of fire fighting, the ignition of the dust cloud and a resulting deflagration are virtually certain. Consequently, when portable fire extinguishers are used in areas that contain accumulated combustible dusts, the extinguishing agent should be applied in a manner that does not disturb or disperse accumulated dust. Generally, fire extinguishers are designed to maximize the delivery rate of the extinguishing agent to the fire. Special techniques of fire extinguisher use should be employed to prevent this inherent design characteristic of the fire extinguisher from producing an unintended deflagration hazard. [**652:**A.9.8.3.2]

N **A.9.8.3.2.1** A nozzle listed or approved for use on Class C fires produces a fog discharge pattern that is less likely than a straight stream nozzle to suspend combustible dust, which could otherwise produce a dust explosion potential. [**652:**A.9.8.4.2.1]

N **A.9.8.3.2.2** 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. [**652:**A.9.8.4.2.2]

N **A.10.3.1** 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

[**652:**A.8.3.1]

For manual operations, the procedures and practices should describe techniques, procedural steps, and equipment that are intended to minimize or eliminate combustible dust hazards. [**652:**A.8.3.1]

Operating procedures and practices should be reviewed on a periodic basis, typically annually, to ensure they are current and accurate.
[**652:**A.8.3.1]

N **A.10.3.2** Safe work practices include, but are not limited to, hot work, confined space entry, and lockout/tagout, and the use of personal protective equipment. *(See NFPA 51B.)* Consideration for extending the duration of the fire watch could be warranted based on characteristics of the material, equipment configuration, and conditions. For example, the PRB Coal Users' Group practice for hot work suggests fire watches could be warranted for 2 to 12 hours following the completion of hot work due to the exothermic chemical reaction of subbituminous coals. In addition to the hazards of combustible dust, safe work practices should address the hazards of mitigation systems such as inerting and suppression. [**652:**A.8.3.2]

N **A.10.4.1.4.3** Corrective actions should be expedited on high-risk hazards (those that could result in a fatality or serious injury). Where in-kind repairs cannot be promptly implemented, consideration should be given to providing alternate means of protection. [**652:**A.8.7.4]

A.10.4.3 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.10.5.1.1 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.10.5.1.2 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.10.5.1.6 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.10.5.2.1 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.10.5.2.6 See NFPA 499.

A.10.5.3 Table A.10.5.3 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. Fire-fighting 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.10.5.3.1 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.10.5.3.5(5) Nitrogen can be considered as an extinguishing agent for iron, steel, and many alkali metals. Gaseous nitrogen 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.10.5.3.9 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.10.5.3.9.2.1 Milling of aluminum with combustible 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 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.10.5.3.9.2.2 Re-ignition can occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

A.10.5.3.10.1 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.

Δ Table A.10.5.3 Combustible Metal Fire-Extinguishing Agents Quick Reference Chart

	Metals								
Extinguishing Agents	**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.
[a]Graphite includes powders, expanded graphite, and carbon microspheres (coke).
[b]Preferred extinguishing agent.
[c]Aqueous 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.

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.10.5.3.10.3 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.10.5.4.1 Where employees are expected to conduct any type of fire-fighting 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.

A.10.5.4.8.1 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.10.5.4.9.1 One of the greatest dangers to fire fighters 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 fire-fighting 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.10.5.4.9.2 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.10.5.5.2.2 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 fire fighters 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 fire-fighting officer.

N **A.10.6.1** 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. [**652:**A.8.8.1]

N **A.10.6.2** 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. [**652:**A.8.8.2]

N **A.10.6.2.1** Safe work habits are developed and do not occur naturally. The training program should provide enough background information regarding the hazards of the materials and the process so that the employees can understand why it is important to follow the prescribed procedures. Training should address the following:

(1) The hazards of their working environment and procedures in case of emergencies, including fires, explosions, and hazardous materials releases
(2) Operating, inspection, testing, and maintenance procedures applicable to their assigned work
(3) Normal process procedures as well as emergency procedures and changes to procedures
(4) Emergency response plans, including safe and proper evacuation of their work area and the permissible methods for fighting incipient fires in their work area
(5) The necessity for proper functioning of related fire and explosion protection systems
(6) Safe handling, use, storage, and disposal of hazardous materials used in the employees' work areas
(7) The location and operation of fire protection equipment, manual pull stations and alarms, emergency phones, first-aid supplies, and safety equipment
(8) Equipment operation, safe startup and shutdown, and response to upset conditions

[**652:**A.8.8.2.1]

N **A.10.6.2.3** 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. [**652:**A.8.8.2.3]

A.10.6.3 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 autoignition 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 fire fighters be aware of the dangers of burning alkali metals. When molten alkali metal reacts with materials such as water or 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.10.7.2 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.

N **A.10.7.2.1** 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

[**652:**A.8.10.1]

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. [**652:**A.8.10.1]

Specialized training for the public fire department(s) and industrial fire brigades can be warranted due to facility specific hazards where the methods to control and extinguish a fire can be outside of their normal arena of traditional fire fighting. *(See OSHA's publication, Firefighting Precautions at Facilities with Combustible Dust, for additional information.)* [**652:**A.8.10.1]

A.10.7.2.5 Fire blankets have been found to be effective for extinguishing clothing fires. They should be distributed in plant areas where water is excluded.

A.10.8 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 fire fighters, 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.10.8.1(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.10.8.1(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.11.3 Items that should be included in the housekeeping plan include, but are not limited to, the following:

(1) A risk analysis that considers the specific characteristics of the dust being cleaned (particle size, moisture content, MEC, MIE) and other safety risks introduced by the cleaning methods used
(2) Personal safety procedures, including fall protection when working at heights
(3) Personal protective equipment (PPE), including flame-resistant garments and the need for static-dissipative shoes in accordance with the hazard analysis required by NFPA 2113
(4) Cleaning sequence
(5) Cleaning methods to be used
(6) Equipment, including lifts, vacuum systems, attachments, etc.

N **A.11.3.3** 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.11.3.3 provides an example of an unscheduled housekeeping procedure to limit the time that a local spill or transient releases of dust are allowed to remain before cleaning the local area to less than the threshold housekeeping dust accumulation. The "level accumulation" of combustible dust should be established in the housekeeping program based on the risk of flash fires and secondary explosions from the dust hazards analysis. [**652:**8.4.6.3]

A.11.4.1 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.11.4.2 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.

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Δ **A.11.6** 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.11.6.2 It is recommended that no more than 2.2 kg (5 lb) 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.11.6.3 See NFPA 77.

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N **A.11.6.3.1** If equipment has an integral grounding plug or system, verification of the equipment condition is sufficient.

N **Table A.11.3.3 Unscheduled Housekeeping [652:Table A.8.4.6.3]**

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

A.11.6.6 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.3.3.82 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.11.9.1 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.11.9.3 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 (walls, floors, overheads)

A.12.1 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.

Δ **A.12.3.2.2** Information on spark-resistant fans and blowers can be found in AMCA 99, *Standards Handbook*.

A.12.3.2.4 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.12.3.3 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.12.4.1 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.

A.12.4.4 Finding combustible metal dust or powder within electrical equipment and components should warrant more frequent inspection and cleaning.

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N **A.12.5** 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 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.13.2 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 for Design*, and A.13.2.3.4.

A.13.2.1 This chapter 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.

A.13.2.3.2 The system information and documentation should include the following:

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

The design of the dust collection system should be coordinated with the architectural and structural designs of the areas involved.

A.13.2.3.3 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.

A.13.2.3.4 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 1372 m/min (4500 ft/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 1676 to 1829 m/min (5500 to 6000 ft/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 for Design.*

A.13.2.3.6.2 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. [**652:**A.8.3.3.3.1]

This design also requires that the hood be constructed to assure that a continuous airflow is provided at all times. [**652:**A.8.3.3.3.1]

The ACGIH publication, *Industrial Ventilation — A Manual of Recommended Practice on Design,* 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. [**652:**A.8.3.3.3.1]

A.13.2.3.6.3 Proper dust collection system design requires that a minimum air volume flow be maintained for each dust collection point source (i.e., 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, at a minimum, the design flow and operating properly.

A.13.2.3.6.4 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 (i.e., hood). When a branch line is disconnected, blanked off, or otherwise modified (e.g., manual slide or blast gate), the modification 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 devices can lead to uncontrolled modification of the flow volumes for both a single line and a system as a whole. The results often lead to improper balance of the system airflows and material accumulations in the ducts. Proper design methods (e.g., balanced-by-design) inherently assure minimum airflows and duct velocities without the use of manual slide or blast gates.

A.13.2.3.6.5 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 for additional system performance can result in a system performing below the minimum required for keeping the ducts free from material accumulations.

A.13.2.3.6.6 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.13.2.3.6.6(a) and Figure A.13.2.3.6.6(b) for illustrations of both methods.

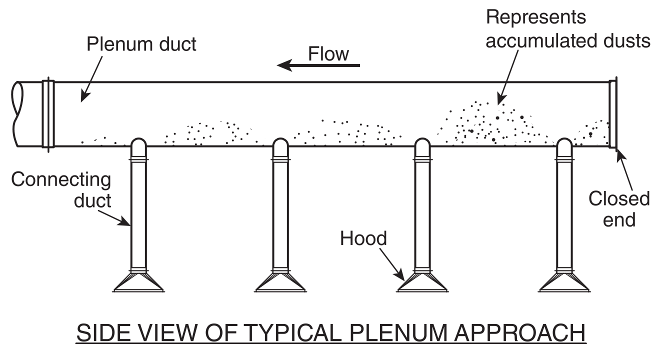

FIGURE A.13.2.3.6.6(b) Plenum Approach.

Δ **A.13.2.3.6.7** 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.

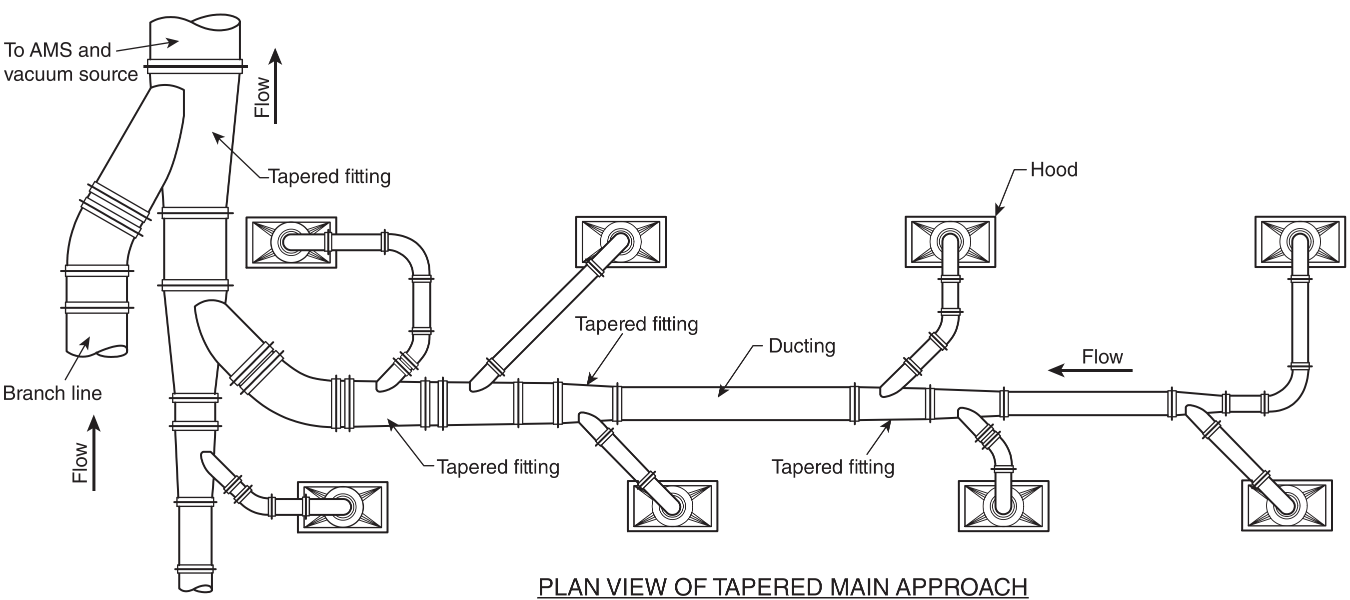

FIGURE A.13.2.3.6.6(a) Tapered Main Approach.

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 9.7.3.3.

A.13.2.3.6.8 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.13.2.3.6.9 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.13.2.3.6.10 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 considerations 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.13.2.3.6.11 The importance of locating the control and monitoring equipment where 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 controls and monitoring equipment would potentially be at risk.
(2) Where the AMS is provided with deflagration venting, NFPA 68 describes the danger zone resulting from the actuation of the vent.

To address the listed situations, it is possible to provide blast protection for personnel who must be in the danger zone.

A.13.2.3.6.12 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 U.S. 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.

Δ **A.13.2.3.7** 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.13.2.4.1 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.13.2.4.2 For more information on static (i.e., electrostatic) electricity, see NFPA 77.

N **A.13.2.4.2.2.1** 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.13.2.4.2.2.3 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.13.2.4.3.2 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.13.2.4.3.3 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.13.2.4.3.4 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 hood performance, and accumulations of combustible dusts.

A.13.2.4.3.5 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.13.2.4.4 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 microns 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 microns 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.13.2.4.4(a) through Figure A.13.2.4.4(d) for examples of dry-type AMS.

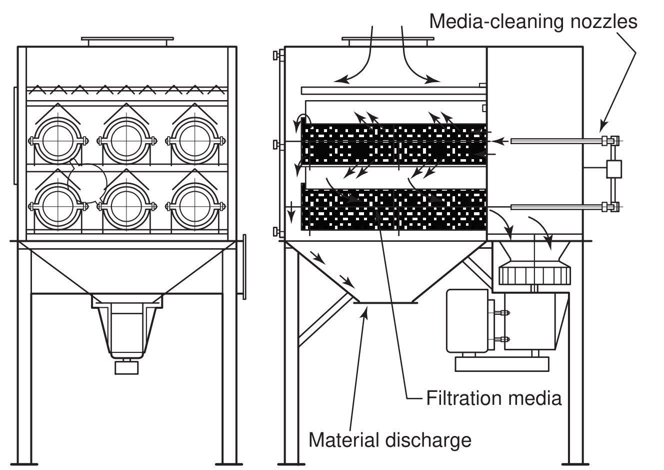

FIGURE A.13.2.4.4(a) Typical Downflow Cartridge Dry-Type AMS.

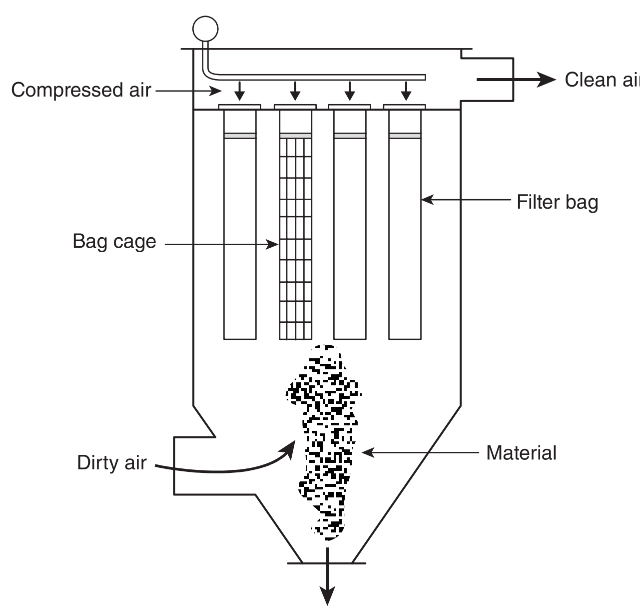

FIGURE A.13.2.4.4(b) Typical Pulse-Jet Dry AMS/Dust Collector.

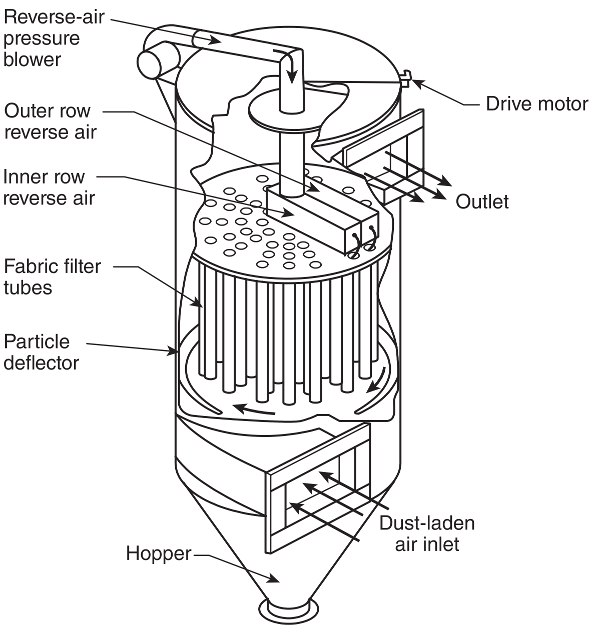

FIGURE A.13.2.4.4(c) Typical Reverse-Air Dry AMS/Dust Collector.

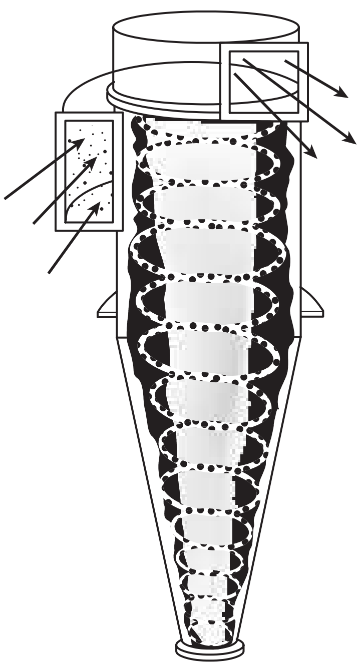

FIGURE A.13.2.4.4(d) Typical Cyclonic AMS.

A.13.2.4.4.1 Historical data show that the application of effective explosion suppression, explosion isolation, and explosion 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.

N **A.13.2.4.4.2(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 static dissipative filter media. See A.13.6.4 for information on the concerns with static dissipative filter media.

N **A.13.2.4.4.2(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 hazard analysis (DHA) conducted in accordance with Chapter 7.

A.13.2.4.4.3 Condensing moisture might cause material to stick to interior surfaces and can exothermically react with most combustible metals generating hydrogen.

A.13.2.4.4.4.1 Electrostatic collectors inherently introduce a potential ignition source based on their method of operation.

A.13.2.4.4.4.3 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.

N **A.13.2.4.4.4.4** Examples of environmental control booths are buffing, grinding, and finishing booths.

A.13.2.4.4.5 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.

N **A.13.2.4.4.7.2** 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.

N **A.13.2.4.4.8.1** 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.13.2.4.4.9 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:

(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.13.2.4.4.10.1 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.

N **A.13.2.4.4.11.2** 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 9.7.3.3.

Δ **A.13.2.4.4.11.2(1)** Explosion 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.

Δ **A.13.2.4.4.11.2(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.

Δ **A.13.2.4.4.11.2(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 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.13.2.4.4.11.2(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.13.2.4.4.11.2(5) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling.

Δ **A.13.2.4.4.11.2(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.

Δ **A.13.2.4.4.11.4(A)** 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.

N **A.13.2.4.4.12.1** 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.13.2.4.4.13 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 for Design*, should be followed.

A.13.2.4.4.13.1(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 2300°C (4172°F) include iron, copper, nickel, zinc, and lead.

A.13.2.4.4.13.1(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.13.2.4.4.13.1(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.13.2.4.4.15 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 fire-fighting 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.13.2.4.4.15.3(E) 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.13.2.4.4.15.4 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 5 m (16.4 ft) 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 13.2.4.4.13). 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.13.2.4.4.15.5 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.13.2.4.4.15.6(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.13.2.4.4.15.7 It is recommended that indoor dry-type AMS for all combustible metals meet these requirements.

A.13.2.4.4.15.7(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.10.5.3 should be consulted to determine if water is an effective extinguishing agent.

For metals not listed in Table A.10.5.3, 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 fire fighters responsible for fighting fires at the facility.

A.13.2.4.4.15.7(A) 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.13.2.4.4.15.7(C)(3) Some fire-extinguishing agents can cause an oxygen deficient atmosphere.

A.13.2.4.4.16 See Figure A.13.2.4.4.16.

A.13.2.4.4.16.3(A) 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.

N **A.13.2.4.4.16.3(B)** 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.13.2.4.4.16.10 It is recommended that each use without a new connection to ground is considered a single use.

A.13.2.4.4.16.12 The purpose is to limit the maximum amount of collected dusts to 2.2 kg (5 lb) at any time. It is good practice to empty this device daily, even if the 2.2 kg (5 lb) limit is not reached.

A.13.2.4.4.17.1 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.

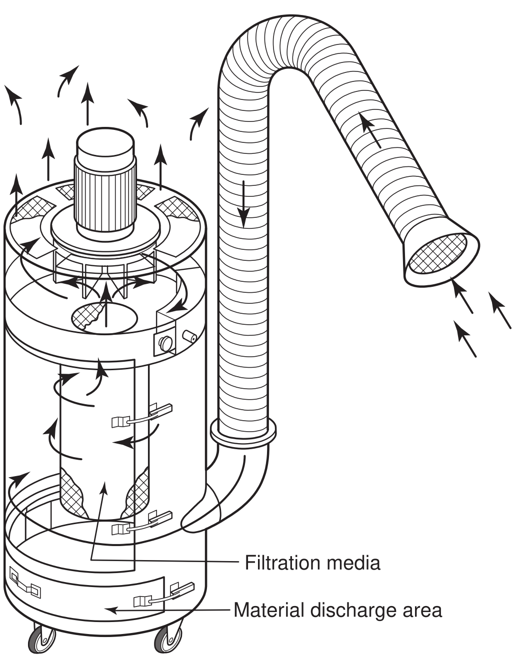

FIGURE A.13.2.4.4.16 An Example of a Portable Media-Type Dust Collector.

A.13.2.4.4.17.2 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.13.2.4.4.17.3 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, cigarettes, and other materials are able to propagate further through a dust collection system.

A.13.2.4.5 Figure A.13.2.4.5(a), Figure A.13.2.4.5(b), Figure A.13.2.4.5(c), and Figure A.13.2.4.5(d) show examples of liquid precipitation collectors.

A.13.2.4.5.5 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.

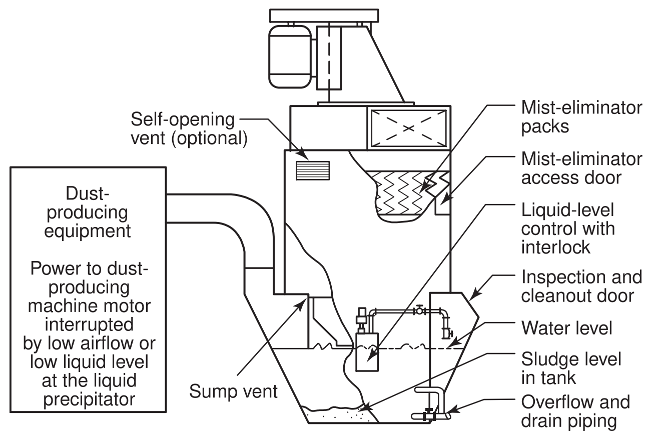

FIGURE A.13.2.4.5(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

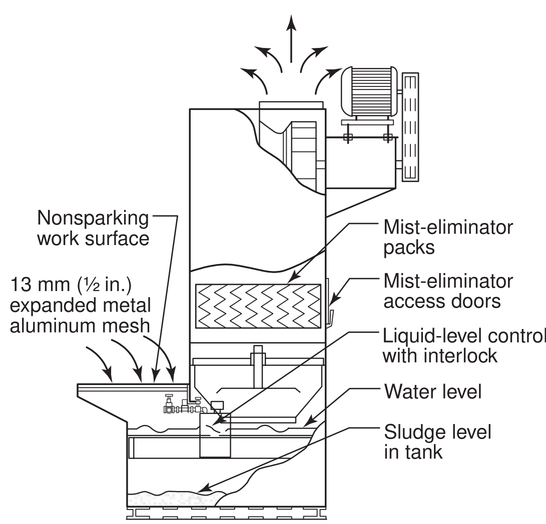

FIGURE A.13.2.4.5(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

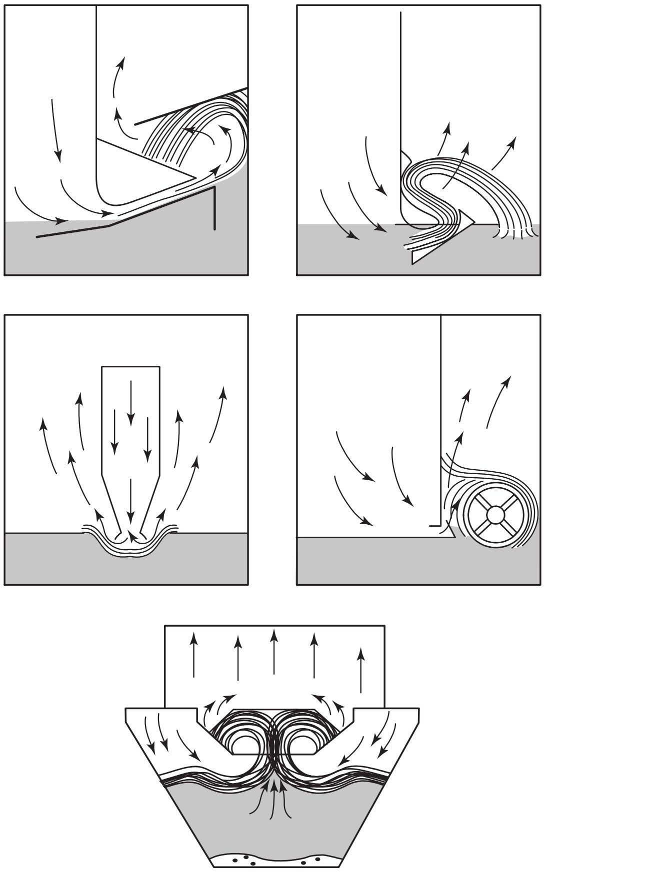

FIGURE A.13.2.4.5(c) Five Methods of Precipitating Dust in Precipitators.

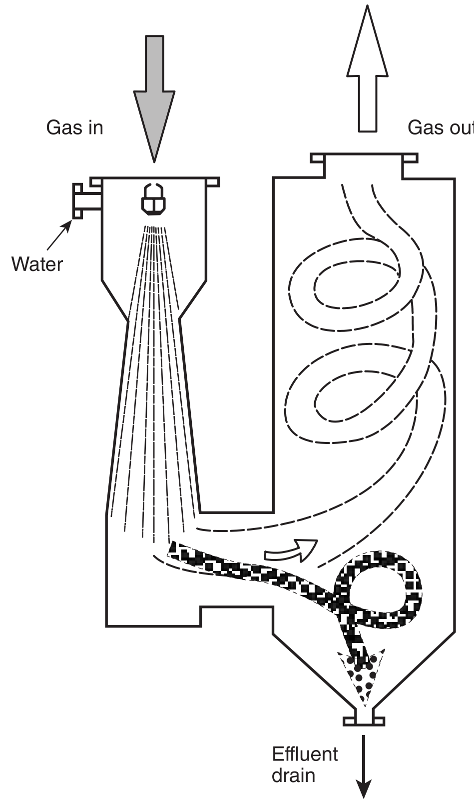

FIGURE A.13.2.4.5(d) Typical Venturi-Style Wet-Type AMS/ Scrubber.

A.13.2.4.5.6 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 (i.e., usually a fan package) and monitoring the performance of both.

A.13.2.4.5.8.1 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.13.2.4.5.9 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.13.2.4.5.9.1 Containers preferably should not hold more than 23 kg (50 lb) each.

A.13.2.4.5.10 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, 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.13.2.4.5(a), Figure A.13.2.4.5(b), Figure A.13.2.4.5(c), and Figure A.13.2.4.5(d).]*

A.13.3 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.13.3 for typical components of a centralized vacuum cleaning system.

A.13.3.1.1 The system information and documentation should include the following:

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

A.13.3.1.2 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.

A.13.3.1.3 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).

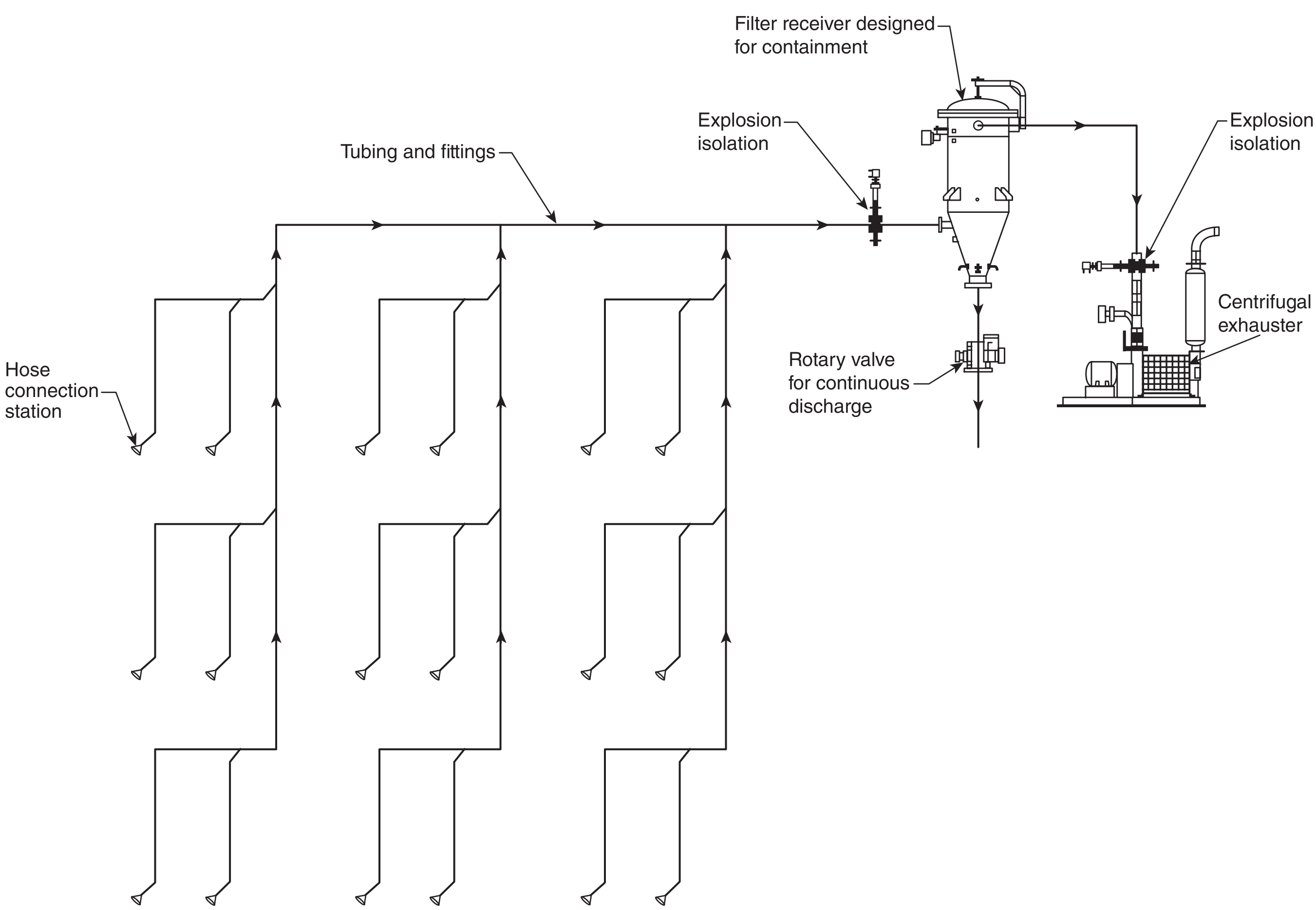

FIGURE A.13.3 Typical Components of a Centralized Vacuum Cleaning System.

A.13.3.2 A centralized vacuum cleaning system represents a significant deflagration risk due to the fact that it is designed to both collect and convey combustible dusts, and that tramp metals or other foreign materials, which could create an ignition source, can enter the system through the vacuum cleaning process. However, through proper design and protection of the system against deflagration, this system can provide for the removal of combustible dusts from the 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.13.3.2.1 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.

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 in the same range as the minimum required for pneumatic conveying of the same material.

A.13.3.2.2 It is recommended that 38.1 mm (1.5 in.), 50.8 mm (2.0 in.), or both size inner diameter (ID) hoses be used for housekeeping purposes. It is also recommended that 7.6 m (25 ft) 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.

Hose of 38.1 mm (1.5 in.) ID are most commonly used for cleaning around equipment and for light-duty requirements, while 50.8 mm (2 in.) ID hoses are used for larger dust accumulations, reduction of air-material concentrations, and for cleaning large open areas.

A.13.3.2.3 Since most metal dusts are sensitive to electrostatic discharges, it is critical that proper grounding and bonding be achieved with all vacuum tools used.

A.13.3.2.4 The creation of static electrical charges is a high-risk factor with most metal dusts and can be minimized through the use of conductive vacuum cleaning tools and static-dissipative and grounded hose.

A.13.3.2.6 For information on static electricity, see NFPA 77.

A.13.3.2.7 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.13.3.2.8 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.13.3.2.9 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.

Δ **A.13.4.2** 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 electrical AMD, as well as an AMS that is either dry or wet. *(See also 8.4.2.2 of NFPA 652.)*

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A.13.5.1.3 For more information on static electricity, see NFPA 77.

A.13.5.1.4 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.13.5.1.5 Typically, the minimum conveying velocities range from 1078 m/min (3500 ft/min) to 1372 m/min (4500 ft/min) depending on the material being conveyed. For further information, refer to the ACGIH's publication, *Industrial Ventilation — A Manual of Recommended Practice for Design.*

Δ **A.13.5.1.6** For information on spacing and sizing of ductwork deflagration vents, see NFPA 68.

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A.13.5.2.1 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.13.5.2.3 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 U.S. Bureau of Mines publication RI 3722, "Inflammability and Explosibility of Metal Powders."

A.13.5.2.4 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.13.5.2.6 Condensing moisture can cause material to stick to ducts and can exothermically react with most combustible metals generating hydrogen.

A.13.5.2.7 Condensing moisture might cause material to stick to ducts and can exothermically react with most combustible metals, generating hydrogen.

A.13.5.2.8 Typically, the minimum conveying velocities range from 1078 m/min (3500 ft/min) to 1372 m/min (4500 ft/min) depending on the material being conveyed. For further information, refer to the ACGIH's publication, *Industrial Ventilation — A Manual of Recommended Practice for Design*.

A.13.5.3.4 Ultimately, all fans or blowers in dust collection systems accumulate sufficient powder to become a potential explosion hazard.

A.13.6.1 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 15 m (50 ft) from any other building or operation. It is not customary to permit personnel to be within 15 m (50 ft) of the collector during operation or when shaking bags. Explosion 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.13.6.1.2 See NFPA 68 for the method to calculate the length of a fireball issuing from a vented collector.

• *N* **A.13.6.1.3** The purpose of this requirement is to ensure that a metal fire is contained within the equipment.

A.13.6.1.5 For information on precautions for static electricity, see NFPA 77.

A.13.6.1.7 Explosion venting is especially important for combustible metal dust due to the high maximum explosion pressures reached and the extremely high rate of pressure rise.

For information on the design of explosion vents and predicting the size of the fireball, see NFPA 68. Dust collectors, when provided by a manufacturer for other applications, seldom have properly sized venting to handle a combustible metal dust explosion.

A.13.6.2.2 The blank is provided for segregation and must be removed before restoring the equipment to operation.

A.13.6.4 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.14.2 Nanometal powder provisions in Chapter 14 and the rest of this standard 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.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.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.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., A. Vorozhtsov, Sh. Guseinov, and P. Storozhenko, "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.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.14.3.2.1 Figure A.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.

A.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.14.3.3.3 Examples of 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.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.)*

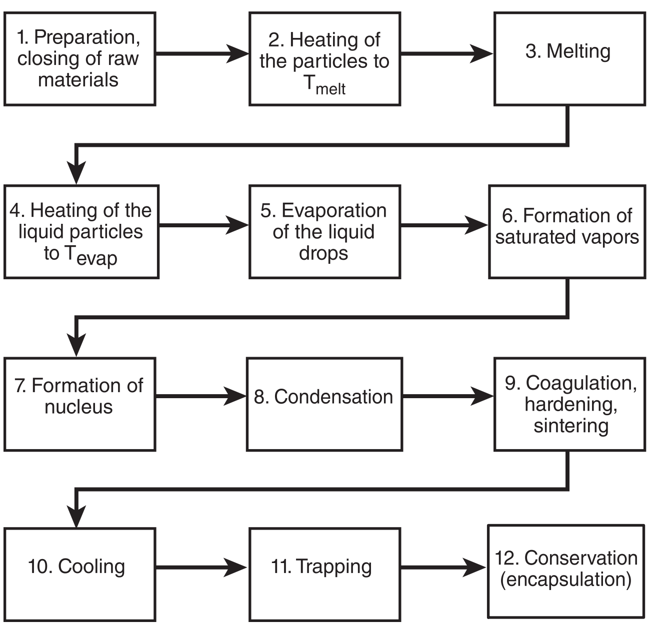

FIGURE A.14.3.2.1 Essential Stages of Plasma-Chemical Process to Produce Disperse NP by Recondensation.

Bioprocess safety guidelines are available in *Guidelines for Process Safety in Bioprocess Manufacturing Facilities*.

A.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.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 A.1.1.3(b) and in NFPA 69, which are based on micrometer-sized dust samples. *(See Mittal, 2013.)*

A.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.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.

N **A.15.2** Powder-based additive manufacturing machines are currently not listed. Many additive manufacturing machines are provided with CE declarations of conformance and might not be independently tested by third-party laboratories. *NFPA 70* and OSHA, 29 CFR 1910.303b(2), require electrical equipment to be listed. Some localities permit a listing through a third-party field evaluation.

Δ **A.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. Inerting decisions should be based on the combustibility properties of the particular alloys being used. The DHA should include the need for inerting, proper PPE, and other fire and explosion protection measures during all the operations delineated in Section 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.

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A.15.2.3 See NFPA 79 for further information on emergency shutdown. The 22.7 kg (50 lb) threshold was established by the technical committee based on the higher hazard posed by handling large quantities of material.