NFPA® 484

Standard for Combustible Metals

2015 Edition

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An International Codes and Standards Organization

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NFPA® 484

Standard for

Combustible Metals

2015 Edition

This edition of NFPA 484, *Standard for Combustible Metals*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and released by the Correlating Committee on Combustible Dusts. It was issued by the Standards Council on April 29, 2014, with an effective date of May 19, 2014, and supersedes all previous editions.

This edition of NFPA 484 was approved as an American National Standard on May 19, 2014.

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, NFPA 484 provided safety requirement, including processing, storage, handling, dust collection, housekeeping, and fire protection, for all combustible metals.

The 2006 edition of NFPA 484, *Standard for Combustible Metals*, contained several major changes, including a new title. A new chapter, Chapter 4, gave 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 given in Chapters 5 through 12.

The 2009 edition of NFPA 484 contained the following changes:

(1) Addition of a new Chapter 14, Combustible Metal Recycling Facilities
(2) Addition of thresholds in Table 1.1.9, for applicability of the document; prior to 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 forms, 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 testing and classification of potentially combustible metals.
(3) Management of change requirements was added to chapters where it was not previously identified as a requirement.
(4) New information was included on wet dust collection systems. Additional information was added addressing housekeeping, an important issue for the prevention of fires and explosions. Personal protective equipment (PPE) requirements were 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. Additional information was added to address emergency response requirements.
(7) Hazard analysis requirements were applicable to all metal chapters.
(8) A new chapter on performance-based design was added.

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

Correlating Committee on Combustible Dusts

Kevin Kreitman, *Chair*
City of Redding Fire Department, CA [E]

Chris Aiken, Cargill, Inc., MN [U]
Matthew J. Bujewski, MJB Risk Consulting, MO [SE]
John M. Cholin, J. M. Cholin Consultants Inc., NJ [SE]
Gregory F. Creswell, Titanium Metals Corporation (TIMET), PA [M]
Scott G. Davis, GexCon US, MD [SE]
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Walter L. Frank, Frank Risk Solutions, Inc., DE [SE]
Donald Hayden, Closure Systems International, IN [U]
Edward R. LaPine, Aon Fire Protection Engineering Corporation, AZ [I]
Jack E. Osborn, Airdusco, Inc., TN [M]
George Petino, Jr., Hazards Research Corporation, Inc., NJ [U]
Rep. Mars Inc.
Bill Stevenson, CV Technology, Inc., FL [M]
Jerome R. Taveau, Fike Corporation, MO [M]

Alternates

Craig Froehling, Cargill, Inc., MN [U]
(Alt. to C. Aiken)
Dale C. Hansen, Harrington Group, Inc., GA [U]
(Alt. to G. Petino, Jr.)
Jason Krbec, CV Technology, Inc., FL [M]
(Alt. to B. Stevenson)
Steve McAlister, Michelin Tire Corporation, SC [U]
(Voting Alt. to Michelin Rep.)

Nonvoting

Matthew I. Chibbaro, U.S. Department of Labor, DC [E]
Mark W. Drake, Liberty Mutual, KS [I]
Rep. TC on Combustible Metals and Metal Dusts
William R. Hamilton, U.S. Department of Labor, DC [E]
Paul F. Hart, American International Group, Inc. (AIG), IL [I]
Rep. TC on Fundamentals of Combustible Dusts
Timothy J. Myers, Exponent, Inc., MA [SE]
Rep. TC on Agricultural Dusts
Jason P. Reason, Lewellyn Technology, IN [SE]
Rep. TC on Wood and Cellulosic Materials Processing
Mark L. Runyon, Marsh Risk Consulting, OR [I]
Rep. TC on Handling and Conveying of Dusts, Vapors, and Gases

Guy R. Colonna, NFPA Staff Liaison

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

Committee Scope: This Committee shall have primary responsibility for documents on the 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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Liberty Mutual, KS [I]

Donna R. Bruce, *Secretary*
KEMET Electronics Corporation, SC [U]

J. Tony Allers, City of Gallatin, TN [E]
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Matthew J. Brown, United States Steel Corporation, PA [M]
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Peter F. Downing, Environment & Safety Solutions, Inc., NJ [SE]
Robert J. Eaker, The Boeing Company, WA [U]
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Daniel J. Hubert, Janus Fire Systems, IN [M]
Steven L. Klima, Babcock & Wilcox Y-12, LLC, TN [U]
Dehong Kong, Princeton Safety Solutions, Inc., NJ [SE]
Kevin Kreitman, City of Redding Fire Department, CA [E]
Kevin M. Laporte, ProVent, LLC, MI [M]
Peter Levitt, Sternvent Division of Durex, Inc., NJ [M]
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Patrick A. Thornton, Oak Ridge National Laboratory, TN [U]
Erdem A. Ural, Loss Prevention Science & Technologies, Inc., MA [SE]
Richard S. Varga, Niagara Metallurgical Products, Canada [U]
David K. Young, Hughes Associates, Inc., ID [SE]
Robert G. Zalosh, Firexplo, MA [SE]

Alternates

Ashok Ghose Dastidar, Fauske & Associates, LLC, IL [U]
(Alt. to S. C. Evans)
Stanley C. Kavel, Jr., Liberty Mutual Property, PA [I]
(Alt. to M. W. Drake)
John E. McConaghie, Magnesium Elektron Powders NJ, NJ [U]
(Alt. to R. S. Varga)
Van Mitchell, Logan Aluminum Inc., KY [U]
(Alt. to B. D. Burridge)
Aaron C. Pack, ATI-Wah Chang, OR [M]
(Alt. to J. Belfanti)
Lon L. Scholl, Fike/Suppression Systems Inc., PA [M]
(Alt. to R. Seidel)
Brooke Williams, Babcock & Wilcox Y-12, LLC, TN [U]
(Alt. to S. L. Klima)

Guy Colonna, NFPA Staff Liaison

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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.

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NFPA 484

Standard for

Combustible Metals

2015 Edition

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

A reference in brackets [ ] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, the complete title and edition of the source documents for extracts in mandatory sections of the document are given in Chapter 2 and those for extracts in informational sections are given in Annex J. Extracted text may be edited for consistency and style and may include the revision of internal paragraph references and other references as appropriate. Requests for interpretations or revisions of extracted text shall be sent to the technical committee responsible for the source document.

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

Chapter 1 Administration

1.1* Scope. This standard shall apply to the production, processing, finishing, handling, recycling, storage, and use of all metals and alloys that are in a form that is capable of combustion or explosion.

1.1.1* The procedures in Chapter 4 shall be used to determine whether a metal is in a noncombustible form.

1.1.2 Combustible Metal Powder or Dust.

1.1.2.1 This standard also shall apply to operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible powder or dust.

1.1.2.2 Operations where metal or metal alloys are subjected to processing or finishing operations that produce combustible powder or dust shall include, but shall not be limited to, machining, sawing, grinding, buffing, and polishing.

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 shall apply to mixtures that contain metals exhibiting combustion characteristics of metals covered by this standard.

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

1.1.6.2* Metal-containing mixtures shall be permitted to be excluded from this standard and protected according to NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, or other NFPA industry- or commodity-specific standard, if by testing it is established 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 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 metal/metal-oxide mixture (e.g., thermite).

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, use, or store more than 0.23 kg (½ lb) of alkali metals or 0.907 kg (2 lb) aggregate of other combustible metals, excluding alkali metals.

1.1.10 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.

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

1.2 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.

1.3 Application.

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

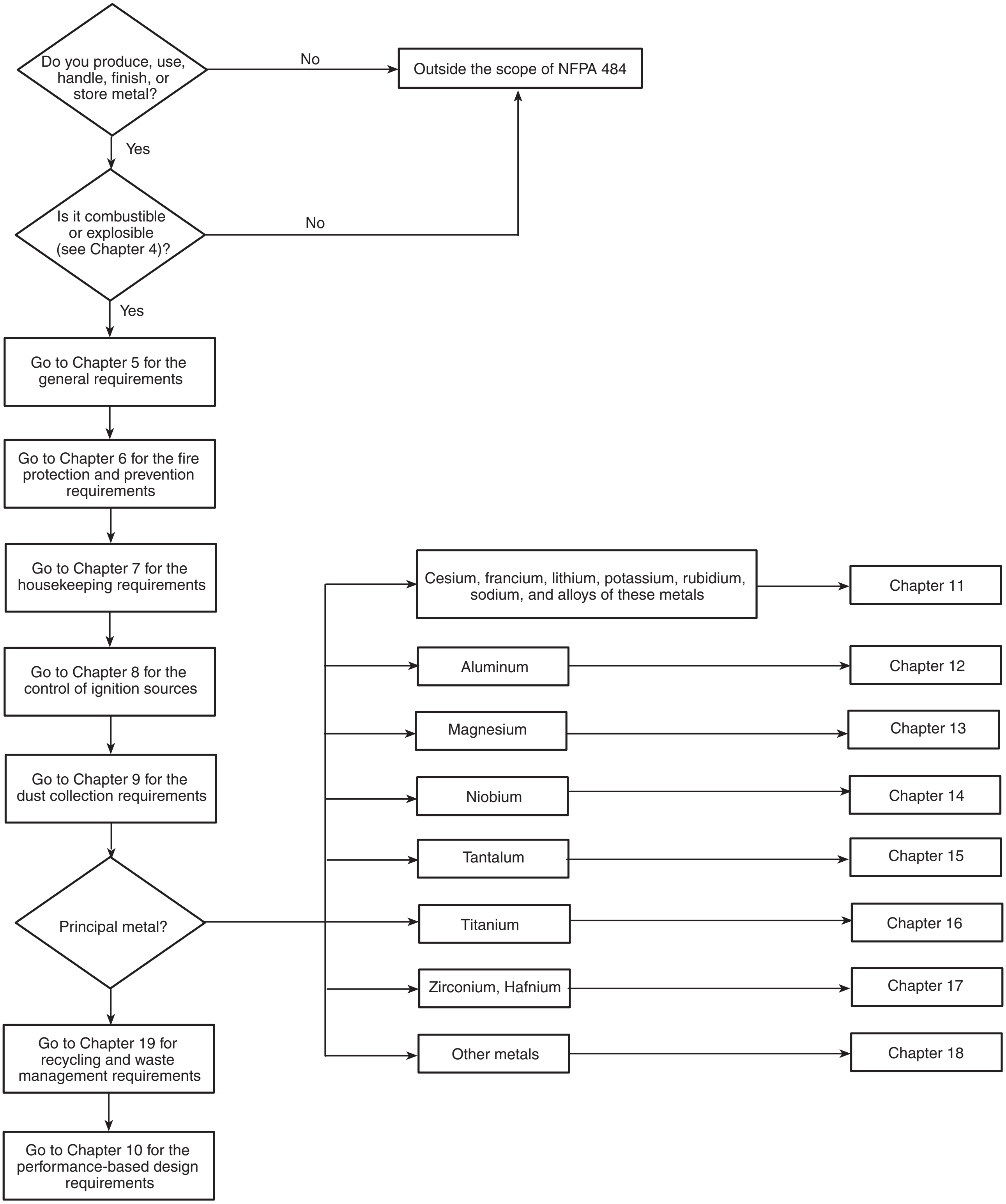


FIGURE 1.3.1 Navigation Flow Diagram.

1.3.2 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.

1.3.3 The provisions of this document shall reflect situations and the state of the art prevalent at the time the standard was issued.

1.3.4 A hazard assessment shall be performed to resolve any conflicts between the requirements of this standard and any other NFPA code or standard.

1.4 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.

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

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

1.4.2.1 Chapters 6 and 19 shall be retroactive.

1.4.3 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.

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

1.5 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.

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,* 2015 edition.

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

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

NFPA 30, *Flammable and Combustible Liquids Code,* 2015 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2011 edition.

NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids,* 2011 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2014 edition.

NFPA 54, *National Fuel Gas Code,* 2015 edition.

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

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

NFPA 70®, *National Electrical Code*®, 2014 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2013 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2015 edition.

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

NFPA 101®, *Life Safety Code*®, 2015 edition.

NFPA 220, *Standard on Types of Building Construction,* 2015 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2015 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2013 edition.

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

NFPA 600, *Standard on Industrial Fire Brigades,* 2010 edition.

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

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2012 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2014 edition.

NFPA 1081, *Standard for Industrial Fire Brigade Member Professional Qualifications,* 2012 edition.

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

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

NFPA 5000®, *Building Construction and Safety Code*®, 2015 edition.

2.3 Other Publications.

2.3.1 ANSI Publications. American National Standards Institute, Inc., 25 West 43rd Street, 4th Floor, New York, NY 10036.

ANSI/ASME B31.3, *Process Piping Design*, 2010.

ANSI/ISA 84.00.01 *Functional Safety: Safety Instrumental Systems for the Process Industry Sector–Part 2,* 2004.

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

ASTM E 11, *Standard Specification for Wire Cloth and Sieves for Testing Purposes*, 2009.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 2012.

ASTM E 176, *Standard Terminology of Fire Standards*, 2010.

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

ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dust*, 2007.

ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, 2007.

ASTM E 2931, *Standard Test Method for Limiting Oxygen (Oxidant) Concentration of Combustible Dust Clouds*, 2013.

ASTM F 1002, *Standard Performance Specifications for Protective Clothing for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards*, 2006.

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

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

2.3.4 Other Publications.

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

Eckoff, Rolf K., *Dust Explosions in the Process Industries,* third edition, 2003. Butterworth-Heinemann Ltd., Oxford, UK.

Explosibility of Metal Powders, Report of Investigations (RI) 6516, 1964, BuMines, U.S. Department of the Interior, Washington DC, 1965.

GESTIS-DUST-EX, Combustion and Explosion Characteristics of Dusts (database), —Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung, Germany (IFA).

2.4 References for Extracts in Mandatory Sections.

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

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

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

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

NFPA 921, *Guide for Fire and Explosion Investigations,* 2014 edition.

NFPA 5000®, Building Construction and Safety Code®, 2015 edition.

Chapter 3 Definitions

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

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

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

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

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

3.2.5 Shall. Indicates a mandatory requirement.

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

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word "shall" to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions 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 *Manual of Style for NFPA Technical Committee Documents.*

3.3 General Definitions.

3.3.1 Alkali Metals. See 3.3.26.1.

3.3.2 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.

3.3.3 Aluminum Powder. See 3.3.32.3.

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

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

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

3.3.6 Combustible Metal. See 3.3.26.2.

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

3.3.6.2 *Combustible Metal Particulate.* See Combustible Metal Dust 3.3.6.1.

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

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

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

3.3.9 Deflagration Hazard Area.

3.3.9.1 ***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.

3.3.9.2 ***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.

3.3.10 Dryer. A piece of processing equipment using temperature or pressure change to reduce the moisture or volatile content of the material being handled. [**654,** 2013]

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

3.3.12 Dust. See Combustible Metal Dust, 3.3.6.1.

3.3.13 Eutectic Reaction. (Reserved)

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

3.3.15 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.

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

3.3.15.2 ***Ultrafines.*** Particles with size generally less than 1 micron (μm).

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

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

3.3.18 Fugitive Material. See 3.3.23.1.

3.3.19 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.

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

3.3.21 Hot Work. Any work involving burning, spark-producing, welding, or similar operations that is capable of initiating fires or explosions.

3.3.22* 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.

3.3.23 Material.

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

3.3.23.2* ***Pyrophoric Material.*** A chemical with an autoignition temperature in air at or below 54.4°C (130°F). [**5000,** 2015]

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

3.3.24 Media Collector. A bag house or a filter-type cartridge collector used for collecting dust.

3.3.25* Mesh Size. The dimensions of a mesh that are specified in ASTM E 11, *Standard Specification for Wire Cloth and Sieves for Testing Purposes.*

3.3.26* 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.

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

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

3.3.26.3 ***Metal Alloy.*** A multiphase solid that is formed by mixing in the molten state, in which the primary component or matrix phase is a metal and the original composition is retained during size reduction.

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

3.3.27* Minimum Explosible Concentration (MEC). The minimum concentration of a combustible dust suspended in air, measured in mass per unit volume, that will support a deflagration. [**654,** 2013]

3.3.28 Mixtures. (Reserved)

3.3.29* 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.

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

3.3.30.1 ***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.

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

3.3.31.1 ***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.

3.3.32 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.

3.3.32.1* ***Aluminum Flake Powder.*** See 3.3.32.3.

3.3.32.2 ***Aluminum Granular Powder.*** See 3.3.32.3.

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

3.3.32.4* ***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 4.

3.3.32.5 ***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.

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

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

3.3.34 Pyrophoric Material. See 3.3.23.2.

3.3.35* 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.

3.3.36 Replacement-in-Kind. A replacement that satisfies the design specifications.

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

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

3.3.38 Screening Test. For the purposes of this standard, a test performed to determine whether a material, product, or assembly, (a) exhibits any usual fire or explosion related characteristics, (b) has certain expected fire or explosion related characteristics, or (c) is capable of being categorized according to the fire or explosion characteristic in question. [**ASTM E176,** 2010 Modified]

3.3.39 Spark-Resistant Material. See 3.3.23.3.

3.3.40* Sponge. Metal after it has been won from the ore but before it is melted.

3.3.41 Spontaneous Heating. Process whereby a material increases in temperature without drawing heat from its surroundings. [**921,** 2014]

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

3.3.43 Tantalum Powder. See 3.3.32.5.

3.3.44 Tantalum Ultrafines. (Reserved)

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

3.3.46 Threshold Dust Accumulation. An established value of dust accumulation, determined as part of the hazard analysis for a particular enclosure of facility and specific metal, for taking an appropriate action.

3.3.47 Titanium Fines. (Reserved)

3.3.48 Zirconium Fines. (Reserved)

Chapter 4 Determination of the Combustibility or Explosibility of a Metal, Metal Powder, or Metal Dust

4.1* Overview. The screening test in Section 4.3 and in Section 4.4 shall be conducted to determine if a metal is in combustible or explosible form.

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

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

4.1.3 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.

4.1.4 Application of This Document.

4.1.4.1 Only those specific forms of combustible 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.

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

4.1.4.3 Wherever the documentation necessary for compliance with 4.1.2 and 4.1.3 is lacking, the requirements of this document shall apply.

4.1.5* 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.

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

4.1.6 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.

4.2* Basic Material Characterization.

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

4.2.2* 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.

4.3 Determination of Combustibility.

4.3.1* Combustibility shall be determined for metals, metal powders, and metal dusts by the preliminary screening test set forth in the UN Recommendations on the Transport of Dangerous Goods: *Model Regulations — Manual of Tests and Criteria*, Part III, Subsection 33.2.1.

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

4.3.2 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

4.3.3 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.

4.3.4* If the material, in the form tested, ignites and propagates combustion, or ejects sparks from the heated zone after the heat source is removed, the material shall be considered combustible and the standard shall be applicable.

4.3.5* 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.

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

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

4.4 Determination of Explosibility.

4.4.1* The explosibility of metals, metal powders, metal dusts, and alloys of these materials shall be determined by using the flow chart in Figure 4.4.1.

4.4.1.1 If the material is determined to be explosible, some or all of the standard test methods in Figure 4.4.1 shall be performed as needed by the hazard analysis as described in Section 5.2.

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

4.4.2* 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.

4.4.3* 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.

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

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

4.5 Use of Test Data for Hazard Analysis.

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

4.5.2* 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.

4.6* Determination of Flash Fire Potential. (Reserved)

4.7 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

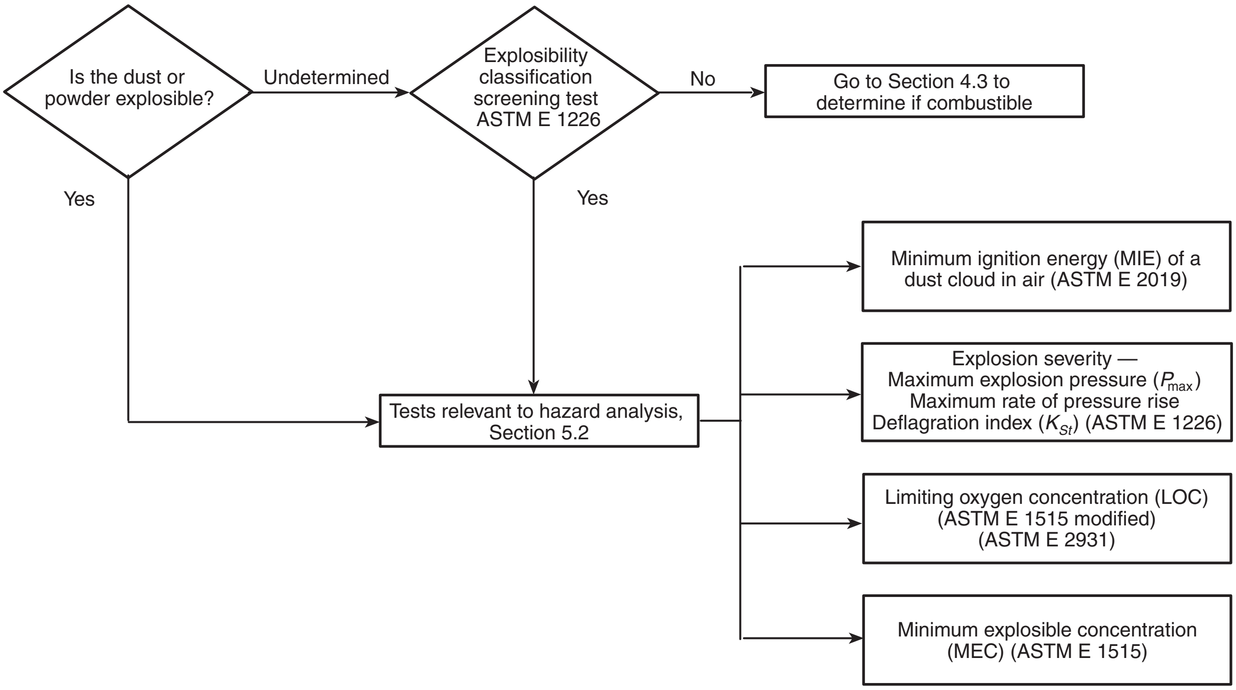


FIGURE 4.4.1 Determination of Explosibility.

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

4.8 Compliance Options. If the material has been determined to be either explosible or combustible by this chapter, compliance shall be achieved by either of the following methods:

(1) The prescriptive provisions in accordance with Chapters 5 through 9 and Chapter 19 of this standard, as well as the applicable specific metal chapter from Chapters 11 through 18
(2) The performance-based provisions in accordance with Chapter 5 through 8 and Chapter 10 of this standard

Chapter 5 General

5.1* Management of Change.

5.1.1 The requirements of 5.1.2 through 5.1.5 shall apply to new and existing facilities and processes.

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

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

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

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

5.1.5 Design documentation shall be updated to incorporate the change.

5.2 Hazard Analysis.

5.2.1* 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.

5.2.2 The results of the hazard analysis shall be documented and maintained for the life of the process.

5.2.3 The hazard analysis shall be reviewed and updated at least every 5 years.

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

5.2.5 Written records shall be maintained of all hazard analyses conducted.

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

5.2.7 Appropriate safeguards shall be put in place with regard to findings of the hazard analysis.

5.2.8 Corrective actions as a result of the hazard analysis shall be tracked and completed to ensure that all identified hazards have been abated or that the level of risk has been reduced to a tolerable level by a knowledgeable authority.

5.3* Personal Protective Equipment (PPE).

5.3.1 PPE Hazard Analysis.

5.3.1.1 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.

5.3.1.2* 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.

5.3.2 Primary PPE for Molten Metals.

5.3.2.1 Primary PPE for molten metals shall include all of the items described in paragraphs 5.3.2.2 to 5.3.2.5.

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

5.3.2.3* 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 for Use by Workers Exposed to Specific Molten Substances and Related Thermal Hazards.*

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

5.3.2.5 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.

5.3.3 Primary PPE for Dust Flash Fires.

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

5.3.3.2* 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.

5.3.3.3 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.

5.3.3.4 Primary PPE for dust flash fires shall include shirts, trousers, or coveralls.

5.3.3.4.1 Trousers or coveralls shall cover the tops of footwear.

5.3.3.5 Primary PPE for dust flash fires shall include safety shoes without exposed metal.

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

5.3.3.7* 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.

5.3.4 Secondary PPE for General Work Areas Near or Containing Combustible Metals.

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

5.3.4.2 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.

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

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

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

5.3.4.5.1* 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, *Standard on Industrial Fire Brigades*, or NFPA 1081, *Standard for Industrial Fire Brigade Member Professional Qualifications.*

5.4 Dust Explosion and Flash-Fire Hazard Areas.

5.4.1 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 11 through 18 — and Chapter 6.

5.4.2 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.

5.5 Segregation, Separation, or Detachment to Limit Dust Hazard Areas.

5.5.1 It shall be permitted to use segregation, separation, or detachment to limit the extent of a dust explosion hazard area or a dust flash-fire hazard area.

5.5.2 Use of Segregation.

5.5.2.1 Physical barriers that are erected to segregate dust flash-fire hazard areas, including seals at all penetrations of floors, walls, ceilings, or partitions shall have a 1-hour fire resistance rating.

5.5.2.2 Physical barriers that are erected to segregate dust explosion hazard areas shall be designed to preclude failure of those barriers during a dust explosion in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting.*

5.5.2.3 Doors and openings shall not be permitted in physical barriers unless they are normally closed and have at least the strength and fire resistance rating required of the physical barrier.

5.5.3 Use of Separation.

5.5.3.1* Where separation is used to limit the dust flash-fire hazard area, the required separation distance between the flash-fire hazard area and surrounding exposures shall be determined by the following:

1. Engineering evaluation that addresses the properties of the materials
2. Type of operation
3. Amount of material likely to be present outside the process equipment
4. Building design
5. Nature of surrounding exposures

5.5.3.2 Where separation is used to limit the dust flash-fire hazard area, in no case shall the required separation distance determined in 5.5.3.1 be less than 11 m (35 ft).

5.5.3.3 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.

5.5.3.4* Where separation is used to limit a dust flash-fire hazard area, the hazard analysis shall be applied to this limited area.

5.5.3.5 Where a limited area is both a dust flash-fire hazard area and a dust explosion hazard area, separation shall not be permitted to be used to reduce the dust flash-fire hazard area.

Chapter 6 Fire Prevention, Fire Protection, and Emergency Response

6.1 Applicability.

6.1.1 The requirements of this chapter shall apply to new and existing facilities where combustible and alkali metals, metal powders, and metal dusts are used, processed, recycled, stored, or handled.

6.2 Fire Prevention.

6.2.1 Inspection and Maintenance.

6.2.1.1 An inspection, testing, and maintenance program shall be implemented that ensures that process controls and equipment perform as designed and that a change in process equipment does not increase the hazard.

6.2.1.2 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).

6.2.1.3 A thorough inspection of the operating area shall take place on an as-needed basis to help ensure that the equipment is in good condition and that proper work practices are being followed.

6.2.1.3.1 The inspection shall be conducted at least quarterly.

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

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

6.2.2 Control of Combustible Materials.

6.2.2.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

6.2.2.1.1 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).

6.2.2.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids.*

6.2.2.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials.*

6.2.2.2 Ordinary Combustible Storage.

6.2.2.2.1 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.

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

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

6.2.2.3.1 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.

6.2.2.3.2 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.

6.2.3* Molten Metal.

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

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

6.3 Fire Protection.

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

6.3.1.1* Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled unless allowed by 6.3.1.2, 6.3.1.3, and 6.3.1.4.

6.3.1.2* Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, 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.

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

6.3.1.4 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.

6.3.1.5 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 6.3.4.

6.3.1.6* 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

6.3.2 Sprinkler Protection for Alkali Metals.

6.3.2.1* 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.

6.3.2.2 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.

6.3.2.3 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, 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.

6.3.2.4 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.

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

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

6.3.3* Extinguishing Agents and Application Techniques.

6.3.3.1* 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.

6.3.3.1.1 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.

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

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

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

6.3.3.4 Portable or wheeled extinguishers listed for use on combustible-metal fires shall be provided and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

6.3.3.5 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 6.3.3)*:

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

6.3.3.6 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.

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

6.3.3.8 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."

6.3.3.9* Solvent-Wetted Powders. Incipient fires in solvent-wetted powders shall be handled according to 6.3.3.9.1 or 6.3.3.9.2.

6.3.3.9.1 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.

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

6.3.3.9.2.1* 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.

6.3.3.9.2.2* 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.

6.3.3.9.2.3 The material shall be handled in covered containers.

6.3.3.10 Applications of Extinguishing Agents. Applications of extinguishing agents shall be handled according to 6.3.3.10.1 through 6.3.3.10.4.

6.3.3.10.1* 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.

6.3.3.10.2 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.

6.3.3.10.3* 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.

6.3.3.10.4 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.

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

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

6.3.4 Fire-Fighting Activities.

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

6.3.4.2 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.

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

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

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

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

6.3.4.7 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.

6.3.4.8 Processing Equipment.

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

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

6.3.4.9 Alkali Metals Fire-Fighting Procedures.

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

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

6.3.5 Fire-Fighting Organization.

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

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

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

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

6.3.5.2.1 Training shall include all possible contingencies.

6.3.5.2.2* 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.

6.4* Emergency Response.

6.4.1 The following information shall be provided to the 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 (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) Water shall not be applied to alkali metals in either a fire or non-fire 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 6.3.3.)*
(12) Use extinguishing agents for containment of small and incipient fires. *(See 6.3.3.)*
(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 compatable 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.

6.5 Emergency Preparedness.

6.5.1 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.

6.5.2* Because of the unique nature of combustible-metal fires, a comprehensive emergency preparedness plan shall be prepared and maintained by the facility owner or operator where combustible metals are processed, handled, used, or stored.

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

6.5.2.2 The plan shall include specific actions in the event of a combustible metal fire and shall be coordinated with the facility management and emergency responders.

6.5.2.3 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

6.5.2.4 The following information on the safe handling of combustible metal fires shall be provided for emergency preparedness planning:

(1) Water, when applied to most burning combustible metals, results in an increase in burning intensity and possible explosion.
(2) Water applied to alkali metals not involved in the fire will result in hazardous decomposition, ignition, or explosion.

(3) Application of carbon dioxide on combustible-metal fire adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres. *(See 6.3.3.)*
(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 6.3.3.)*
(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 6.3.3.)*
(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.

6.5.3 Emergency procedures to be followed in case of fire or explosion shall be established.

6.5.4* 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.

6.5.5 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.

6.5.6 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.

6.5.7* Clothing Fires.

6.5.7.1 Emergency procedures for handling clothing fires shall be established.

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

Chapter 7 Housekeeping

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

7.2* Housekeeping Plan.

7.2.1 A documented housekeeping program shall be established.

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

7.2.3 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.

7.3 Cleanup Procedures for Fugitive Dust Accumulations.

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

7.3.2* 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.

7.3.3 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 7.5

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

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

7.3.5.1 The cleaning shall include machinery.

7.3.5.2 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.

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

7.3.5.4 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.

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

7.4* Cleanup of Spilled Dust, Fine or Powder.

7.4.1 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.

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

7.4.3 Compressed-air blowdown shall be permitted as a method for cleaning only when done in accordance with Section 7.6.

7.5* Vacuum Cleaning.

7.5.1 Vacuum cleaning systems shall be used only for removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly removed by hand brushing.

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

7.5.3* Due to the inherent hazards associated with the use of fixed and portable vacuum cleaning systems for finely divided combustible metal dust, special engineering consideration shall be given to the design, installation, maintenance, and use of such systems. *(See Section 9.2.)*

7.5.4* When being used for combustible metal powder, portable vacuum cleaners shall be used only if listed for the material being vacuumed with the following conditions:

(1) They shall be permitted only for 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

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

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

7.5.7 Assembled components shall be conductive and bonded where necessary.

7.5.8 Periodic tests for continuity shall be performed.

7.5.9 Combustible metal dust picked up by a fixed vacuum cleaning system shall be discharged into a container or collector located outside the building.

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

7.6 Compressed Air Cleaning Requirements.

7.6.1 Compressed air blowdown shall be permitted in areas that are otherwise impossible to clean by vacuuming or other means and shall be performed under carefully controlled conditions with all potential ignition sources prohibited in or near the area and with all equipment shut down.

7.6.1.1 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, Group E 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.

7.6.2 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.

7.7 Water-Cleaning Requirements.

7.7.1 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

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

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

7.8 Cleaning Frequency.

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

7.8.2 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.

7.8.3* 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.

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

7.9 General Precautions.

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

7.9.2 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.

7.9.3 Oil spills shall be cleaned up promptly.

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

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

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

7.9.7 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 8 Control of Ignition Sources

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

8.2* Hot Work.

8.2.1 Hot work operations in facilities covered by this standard shall comply with the requirements of NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, and this section.

8.2.2 Hot work permits shall be required in any areas that contain metals in a combustible form.

8.2.3 Open flames, cutting or welding operations, propellant-actuated tools, and spark-producing operations shall not be permitted in areas where combustible metals are produced, stored, handled, or processed, including disposal areas, unless hot work procedures approved by qualified personnel are followed.

8.2.4 All hot work areas that require a permit shall be thoroughly cleaned of exposed metals in a combustible form before hot work is performed.

8.2.5 All internal sections of grinding equipment, ducts, and dust collectors shall be completely free of moist or dry metals in a combustible form and shall be purged before hot work is performed.

8.2.6 Hot work that is an integral step in a manufacturing process, is routine in nature, and has been reviewed as part of the hazard analysis shall not require a hot work permit.

8.3 Smoking.

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

8.3.2 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.

8.3.3 Smoking shall be permitted only in designated areas.

8.3.4 No-smoking areas shall be posted with "No Smoking" signs.

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

8.4 Spark-Resistant Tools.

8.4.1* 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.

8.4.2* 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.

8.4.3 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.

8.5* Static Electricity.

8.5.1* All permanently installed process equipment and all building structural steel shall be grounded by permanent ground wires to prevent accumulation of static electricity.

8.5.2* Movable or mobile process equipment or tools of metal construction shall be bonded and/or grounded prior to use.

8.5.3* A monitoring and testing schedule shall be established based on the hazard assessment to ensure that the effectiveness of grounding and bonding of fixed and mobile equipment has not failed or deteriorated over time and use.

8.5.4 Static dissipative belts shall be used on belt-driven equipment.

8.5.5 All machinery where nonconductive components present a discontinuity in the grounding path shall be bonded between adjacent conductive components.

8.5.6 Ductwork for Pneumatic Conveying Systems. Bonding and grounding for dust collection and pneumatic conveying shall be in accordance with Chapter 9.

8.5.7* Grounding of Personnel.

8.5.7.1 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.

8.5.7.2 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.

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

8.6.1 Bearings.

8.6.1.1 Ball or roller bearings shall be sealed against dust.

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

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

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

8.6.1.5 Grounded and bonded bearings shall be used.

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

8.6.2 Fan and Blower Construction.

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

8.6.2.2* 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.

8.6.2.3 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.

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

8.6.2.4.1 Bearings shall be equipped with temperature indicating devices.

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

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

8.6.3* Grinding Wheels.

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

8.6.3.2 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.

8.7 Electrical Power and Control.

8.7.1 All electrical equipment and wiring shall be installed in accordance with *NFPA 70, National Electrical Code.*

8.7.2 All process equipment and all building steel shall be bonded and grounded in accordance with *NFPA 70, National Electrical Code.*

8.7.3 All manufacturing buildings shall be provided with emergency lighting systems in accordance with NFPA *101*, *Life Safety Code.*

8.7.4 Control equipment, control rooms, and offices meeting the requirements of NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, shall be permitted.

8.7.5 Preventive maintenance for electrical equipment shall be established commensurate with the environment and conditions.

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

8.7.7 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.

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

8.8 Electrical Area Classification.

8.8.1* In local areas of a plant where combustible or flammable liquids are present, or where combustible metal dust accumulates or is present in suspension in the air, the area shall be classified, and all electrical equipment and installations in those local areas shall comply with Article 500 of *NFPA 70, National Electrical Code.*

8.8.2 All hazardous (classified) areas identified in accordance with 8.8.1 shall be documented, and such documentation shall be maintained on file for the life of the facility.

8.8.3* Electrical equipment and components installed in unclassified locations, where combustible metal dusts are processed or handled, shall be inspected both internally and externally and cleaned at least annually, or more frequently if warranted.

8.8.4 Flashlights and other portable electrical equipment shall be identified for the locations where they are used.

8.9 Powered Industrial Trucks.

8.9.1 Where used, powered industrial trucks shall be selected and maintained in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*.

8.9.2* Where industrial trucks, in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, are not commercially available, a documented risk assessment acceptable to the authority having jurisdiction shall be permitted to be used to specify the fire and explosion prevention features for the equipment used.

8.10 Propellant-Actuated Tools.

8.10.1* 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.

8.10.2 Propellant-actuated tools shall be used in accordance with Section 8.2.

Chapter 9 Dust Collection

9.1 General.

9.1.1 Dust collection systems, vacuum cleaning, and pneumatic conveying of a powder or dust for metals in a combustible form shall comply with the requirements of this chapter.

9.1.2 Dust collection for combustible metal powder production operations shall follow the requirements of Section 9.3.

9.1.3 Dust collection for machining, fabrication, finishing, and other dust-generating operations shall follow the requirements of Section 9.4.

9.2 Pneumatic Conveying of Powder.

9.2.1 Ductwork for Pneumatic Conveying Systems.

9.2.1.1 Conveyor ducts shall be fabricated of spark-resistant metals that are compatible with the metal being transported.

9.2.1.2 Plastics or other nonconductive ducts or duct liners shall not be used.

9.2.1.3* Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge.

9.2.1.4* Where the conveying duct is exposed to weather or moisture, it shall be moisture-tight.

9.2.1.5* 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.

9.2.1.6* If the conveying gas is air, the combustible metal-to-air ratio throughout the conveying system shall be held below the minimum explosible concentration (MEC) of the combustible metal dust at normal operating conditions.

9.2.1.7* Where a deflagration hazard exists, deflagration protection such as rupture diaphragms shall be provided on ductwork.

9.2.1.7.1 Deflagration vents shall relieve to a safe location outside the building.

9.2.1.7.1.1 Where provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

9.2.1.7.1.2 It shall be permissible to determine the deflagration vent discharge area using NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

9.2.1.7.1.3* Where ducts are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING

Explosion relief device

9.2.1.7.2 Deflagration venting shall not be required for ductwork provided with explosion isolation systems identified in NFPA 69, *Standard on Explosion Prevention Systems*, that can prevent propagation of a deflagration into other parts of the process.

9.2.1.8* 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, *Standard on Explosion Prevention Systems*.

9.2.1.9 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.

9.2.2 Conveying Using an Inert Medium.

9.2.2.1* Inert gas–conveying systems shall be permitted if designed in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

9.2.2.2 The inert gas used shall not react with the specific metal.

9.2.2.3* 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, *Standard on Explosion Prevention Systems*.

9.2.2.4* 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.

9.2.2.5 The oxygen concentration of the inert gas stream shall be monitored in accordance with NFPA 69, *Standard on Explosion Prevention Systems*.

9.2.2.6* The inert gas shall have a dew point so that no free moisture can condense or accumulate at any point in the system.

9.2.2.7* 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.

9.2.2.8* 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.

9.2.3 Fan and Blower Construction and Arrangement.

9.2.3.1 Fans and blowers shall be in accordance with 8.6.2.

9.2.3.2 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 and 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).

9.2.3.3 No maintenance shall be performed on the fan until it is shut down.

9.2.3.4* 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.

9.3 Powder Collection.

9.3.1* Collectors.

9.3.1.1 Dry-type collectors shall be located outside in a safe location and shall be provided with barriers or other means of protection for personnel.

9.3.1.2* 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.

9.3.1.2.1 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

9.3.1.2.2* It shall be permissible to determine the deflagration vent discharge area using NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

9.3.1.2.3 Where collectors are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING

Explosion relief device

9.3.1.3 Collectors shall be constructed of metal that is static dissipative.

9.3.1.4 Ductwork shall comply with the provisions of 9.2.1.

9.3.1.5* The entire collection system, including the collector, shall be completely bonded and grounded to minimize accumulation of static electric charge.

9.3.1.6 Recycling of air from powder collectors into buildings shall be prohibited.

9.3.1.7* Where an explosion hazard exists, dry-type collectors shall be provided with deflagration vents.

9.3.1.7.1 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.

9.3.1.7.2 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

9.3.1.7.3 It shall be permissible to determine the deflagration vent discharge area using NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

9.3.1.7.4 Deflagration vents shall be positioned so that a potential blast is not directed toward any combustible or frangible structure.

9.3.1.7.5 Vent closures shall be clearly marked as follows:

WARNING

Explosion relief device

9.3.2 Repairs.

9.3.2.1 Where repairs on dry-type collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed.

9.3.2.2* Ductwork leading into the collector shall be disconnected and isolated by blanking before repair work is permitted to be started.

9.3.3 High-Temperature Warning.

9.3.3.1 Cyclone or other dry-type collectors shall be equipped with instruments for recording the surface temperature.

9.3.3.2 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 (122°F) below the ignition temperature of the powder cloud, whichever is lower.

9.3.3.3 The devices specified in 9.3.3.2 shall give audible and visual alarms at normally attended locations.

9.3.4* Collector Filter Media. Collector filter media made from synthetic fabrics that accumulate static electric charges shall not be used.

9.4* Dust Collection.

9.4.1* Machines that produce fine particles of combustible metal shall be provided with hoods, capture devices, or enclosures that are connected to a dust-collection system having suction and capture velocity to collect and transport all the dust produced.

9.4.2 Hoods and enclosures shall be designed and maintained so that the fine particles will either fall or be projected into the hoods and enclosures in the direction of airflow.

9.4.3* Special attention shall be given to the location of all dust-producing machines with respect to the location of the dust-collection system to ensure that the connecting ducts will be as straight and as short as possible.

9.4.4 The interior of hoods and ducts shall be regularly cleaned wherever there is the possibility of buildup of wax, lint, metal fines, or other combustible material.

9.4.5 Dry-type dust collection systems shall be designed and maintained so that internal cleanliness is ensured. The accumulation of material inside any area of the collector other than in the discharge containers designed for that purpose shall not be permitted.

9.4.6* The accumulation or condensation of water at any point in a dry-type dust collection system shall be prevented.

9.4.7* 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.

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

9.4.9 Operations Generating Hot Metal Particles.

9.4.9.1 For grinding, plasma spray, and other operations generating hot metal particles, 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 medium in the collector.

9.4.9.2 Metal temperatures at the dust collector shall be compatible with the limiting temperature of the filter medium element.

9.4.9.3 Grinding operations shall not be served by the same dust-collection system as buffing and polishing operations.

9.4.10 Dust-Collection Ducts and Ductwork.

9.4.10.1 All dust-collection systems shall be installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

9.4.10.2* Inlet and exhaust ducts shall be designed to maintain a velocity to ensure the transport of both coarse and fine particles and to ensure re-entrainment if, for any reason, the particles can fall out before delivery to the collector (for example, in the event of a power failure).

9.4.10.3* The dust loading in ductwork during normal operating conditions shall be held below the MEC in accordance with the deflagration prevention by combustible concentration reduction methods in NFPA 69, *Standard on Explosion Prevention Systems.*

9.4.10.4* Ducts shall be as short as possible and shall have as few bends and irregularities as possible, to prevent interference with free airflow.

9.4.10.5 Duct Construction.

9.4.10.5.1 Ducts shall be constructed of conductive material and shall be carefully fabricated and assembled with smooth interior surfaces and with internal lap joints facing the direction of airflow.

9.4.10.5.2 There shall be no unused capped outlets, pockets, or other dead-end spaces that might allow accumulations of dust.

9.4.10.5.3 Duct seams shall be oriented in a direction away from personnel.

9.4.10.5.4 Additional branch ducts shall not be added to an existing system without reanalysis of the system.

9.4.10.5.5 Branch ducts shall not be disconnected without evaluation of the system, in order to maintain the minimum required conveying velocity throughout the system.

9.4.10.5.6 Unused portions of the system shall not be blanked off without means being provided to maintain required airflow.

9.4.10.5.7* Duct systems, dust collectors, and dust-producing machinery shall be bonded and grounded to minimize accumulation of static electric charge.

9.4.11* Bonding and Grounding.

9.4.11.1 All components of dust-collection systems shall be bonded and grounded.

9.4.11.2 When continuous contact is interrupted, metallic jumpers shall be installed for effective bonding.

9.4.11.3* Dust-collecting filter media shall be designed to be static dissipative.

9.4.12 Wet-Type Dust Collectors.

9.4.12.1* The exhaust vent shall terminate to a safe location outside the building and shall be securely fastened except as provided in 9.4.12.2.1.

9.4.12.2 The clean air shall not be permitted to be returned to an identified deflagration hazard area.

9.4.12.2.1 The cleaned air shall be permitted to be returned to the work area when tests conducted by an approved testing organization 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.

9.4.12.2.2 The duct shall be as short and straight as possible and shall be designed to withstand the same explosion pressure as the wet-type dust collector.

9.4.12.3* The exhaust vent duct shall be inspected and cleaned frequently to prevent buildup of highly combustible deposits of metal dusts on the interior surfaces of the duct.

9.4.12.4 Arrangement of Wet-Type Dust Collector Components.

9.4.12.4.1 The dust collector shall be arranged so that contact is prevented between dust particles and parts moving at high speed.

9.4.12.4.2 The blower for drawing the dust-laden air into the collector shall be located on the clean-air side of the collector.

9.4.12.4.3* The dust collector shall be arranged so that the dust-laden airstream is thoroughly scrubbed by the liquid to achieve the desired efficiency. The use of an additional dry filter medium either downstream or combined with a wet collector shall not be permitted.

9.4.12.4.3.1 Where required to meet industrial hygiene exposure, dry filter medium shall be permitted to be located downstream of the wet-type collector when equipped with all of the following:

(1) Differential pressure alarm
(2) Static dissipative filter media
(3) A means to limit hydrogen accumulation to 10 percent of the LFL
(4) High-temperature alarm at the filter media limit

9.4.12.5* Collector Sump Venting.

9.4.12.5.1 Wet-type dust collectors shall be designed so that hydrogen generated from metal contacting the water is vented at all times.

9.4.12.5.2 Vents shall remain open and unobstructed when the machine is shut down.

9.4.12.5.3 When the dust collector is not in operation, ventilation shall be permitted to be provided by an independent blower or by an unimpeded vent.

9.4.12.5.4 Each chamber of the collector shall be vented to dissipate the hydrogen.

9.4.12.5.5 Sludge level buildup in the sludge tank of the wet-type dust collector shall not exceed 5 percent of the tank water capacity as measured by volume.

9.4.12.5.6 Sludge shall be removed from the collector whenever the collector is to remain inoperative for a period of 24 hours or more.

9.4.12.5.7 Wet-type dust collectors shall incorporate the use of positive venting of the sludge tank at all times during shutdown by means of an auxiliary blower that is energized when the main exhaust fan is turned off.

9.4.12.5.8 The auxiliary fan volume shall not be less than 10 percent of the exhaust fan volume.

9.4.12.6 Power Supply Interlock.

9.4.12.6.1* The power supply to the dust-producing equipment shall be interlocked with the airflow from the exhaust blower and the liquid-level controller of the collector so that improper functioning of the dust-collection system will shut down the equipment it serves.

9.4.12.6.2 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 collector is in complete operation.

9.4.12.7* Disposal of Sludge from Water Wet-Type Dust Collectors.

9.4.12.7.1 Sludge from water wet-type dust collectors shall be removed at least once each day or more frequently if conditions warrant.

9.4.12.7.2* Covered, vented metal containers shall be used to transport sludge collected for disposal.

9.4.12.7.3 Sludge from wet-type dust collectors shall be permitted to be managed prior to disposal in accordance with applicable federal, state, and local regulations.

9.4.12.7.4 Material removed from wet-type dust collectors 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 five parts inert material to one part metal dust.

9.4.12.7.5* Sludge shall be recycled or disposed of in accordance with federal, state, and local requirements.

9.4.12.7.6 Smoking or open flames shall be prohibited in the disposal area and throughout the disposal process.

9.4.12.7.7 All sludge from wet-type collectors shall be collected in covered, vented metal containers and removed daily, at a minimum, to a safe storage or disposal area that is ventilated.

9.4.12.7.8 Open storage of sludge from wet-type collectors shall be isolated and segregated from other combustible materials and metal scrap to prevent propagation of a fire.

9.4.13* Dry-Type Dust Collectors.

9.4.13.1* Electrostatic collectors shall not be used.

9.4.13.2* Dry-type dust collectors shall be located outside of buildings unless permitted by 9.4.13.15.

9.4.13.3* Individual machines with portable 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 9.4.13.3.1 through 9.4.13.3.4.

9.4.13.3.1 The operation of portable dust-collection devices shall be subject to a hazard analysis to ensure that the risk to personnel and operations from flash fire and shrapnel is minimized.

9.4.13.3.2 Personal protective clothing shall comply with Section 5.3.

9.4.13.3.3 The collector shall be designed to be static dissipative.

9.4.13.3.4* Collector retention capacity shall be limited to 2.2 kg (5 lb).

9.4.13.4 The collector shall be arranged to prevent contact between dust particles and parts moving at high speeds.

9.4.13.5 The blower for drawing the dust-laden air into the collector shall be located on the clean-air side of the collector.

9.4.13.6 Cyclone collectors shall be of conductive metal construction suitable for the service intended.

9.4.13.7 Cyclone collectors shall be solid-welded with smooth internal seams.

9.4.13.8 Discharge containers for collectors shall be emptied before or when 100 percent of the storage capacity of the container is attained.

9.4.13.9 Dust shall be removed from collectors at least once each day and at more frequent intervals if conditions warrant.

9.4.13.9.1 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, it shall be recycled or disposed of in accordance with local, state, and federal regulations.

9.4.13.9.2 Precautions shall be taken to avoid creating dust clouds when removing dust from the collectors.

9.4.13.9.3 The dust removed shall be recycled or disposed of in accordance with local, state, and federal regulations.

9.4.13.10 The dust shall be discharged into metal containers that shall be promptly and tightly covered to avoid the creation of airborne fugitive dust.

9.4.13.11 Recycling of Exhaust Air. Recycling of exhaust air from dry-type dust collectors into buildings shall be prohibited.

9.4.13.12 Repairs.

9.4.13.12.1 Where repairs on dry-type dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed.

9.4.13.12.2 Ductwork leading into the collector shall be disconnected and blanked off before repair work shall be permitted to be started.

9.4.13.13 Explosion Protection.

9.4.13.13.1 Collectors shall be protected by a minimum of one of the following explosion protection methods:

(1)*Deflagration venting in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, which includes the following:
  (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 in accordance with NFPA 68.
  (b)*Vent ducts shall be designed to prevent accumulation of moisture.
(2) Oxidant concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, which includes the following:
  (a) Where oxygen monitoring is used, it shall be installed in accordance with ISA 84.00.01, *Functional Safety: Application of Safety Instrumented Systems for the Process Industry Sector*.
  (b)*Where the chemical properties of the material being conveyed require a minimum concentration of oxygen to control pyrophoricity, that level of concentration shall be maintained.
(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 effective with the metal being collected.

9.4.13.13.2 If the method in 9.4.13.13.1(5) is used, test data for specific dust and dilutent combinations shall be provided and shall be acceptable to the authority having jurisdiction.

9.4.13.13.3 Where an explosion hazard exists and is not protected by 9.4.13.13.1(2) or 9.4.13.13.1(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, *Standard on Explosion Prevention Systems*.

9.4.13.13.3.1* Explosion isolation shall be provided in accordance with NFPA 69, *Standard on Explosion Prevention Systems*, between the dust collector and the upstream.

9.4.13.13.3.2 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.

9.4.13.13.4 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.

9.4.13.13.5 Where collectors are provided with deflagration vents, the area within the deflagration vent's discharge area shall be marked.

9.4.13.13.6 Signage shall be posted near the dust collector that reads as follows:

CAUTION

This dust collector can contain explosible dust. Keep outside the marked area while equipment is operating.

9.4.13.13.7 Where collectors are provided with deflagration vents, vent closures shall be clearly marked as follows:

WARNING

Explosion relief device

9.4.13.14 Media Collectors.

9.4.13.14.1* Media collectors shall not be permitted unless the combustible dust K_{St} is less than 150 bar-m/s and the requirements of 9.4.13.14 are met.

9.4.13.14.2 Media collectors shall not be used for dust being collected in air for metals covered by chapters on niobium, tantalum, titanium, zirconium, and hafnium unless their use is supported by a risk assessment that is acceptable to the AHJ.

9.4.13.14.3 Media dust collectors shall be provided with all of the following ignition prevention measures:

(1) Where the MIE of the dust is less than 1000 mJ, the filter media shall be conductive and shall be effectively bonded to the conductive filter frame.
(2) Accumulations on filter media are 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 shall be determined as part of the dust collection risk analysis conducted in accordance with Section 5.2.
(3) Accumulation levels during operation shall be monitored by a pressure drop across the media or some equivalent sensor and, if the accumulation exceeds the predetermined limits, a controlled shutdown of the collector and dust generation equipment shall be implemented.
(4) Periodic inspections and replacement of media shall be based on intervals determined by the pressure drop across the filter media or by indication of self-heating detection equipment based on moisture reactivity.

9.4.13.14.4* Spark detection and either extinguishing methods or methods of diversion away from the collector shall be installed in the duct away from any operations prone to spark generation. *(See 6.3.3.)*

9.4.13.14.5 The filter media shall not be chemically reactive with the collected dust, including any contaminants carried in the dust stream with the combustible metal.

9.4.13.14.5.1 Reactivity shall be evaluated as part of the documented risk analysis conducted in accordance with Section 5.2.

9.4.13.14.6 The collector design shall prevent the accumulation of hydrogen due to a metal-moisture reaction.

9.4.13.14.7* 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.

9.4.13.15 Indoor Dry-Type Dust Collectors.

9.4.13.15.1 Indoor dry-type dust collectors shall be permitted for only metals covered by Chapter 18.

9.4.13.15.2 Enclosureless collectors shall be prohibited.

9.4.13.15.3 Self-contained, dry down draft benches shall be prohibited.

9.4.13.15.4 Dry-type dust collectors shall be permitted to be located indoors where the requirements of 9.4.13.15.4.1 and 9.4.13.15.4.2 are met.

9.4.13.15.4.1 A hazards analysis shall be conducted in accordance with Section 5.2 to ensure that the risk to personnel and operations is minimized for both new and existing systems.

9.4.13.15.4.2* The material being collected shall meet all of the following criteria:

(1) The P_{max} is less than 8 bar-g as measured using the ASTM E1226 test method.
(2) The K_{St} is less than 150 bar-m/s as measured using the ASTM E1226 test method.
(3) The minimum ignition energy (MIE) is greater than 100 mJ as measured using the ASTM E2019.
(4) The material is not a UN Class 4.2 solid as tested using UN 4.2 self-heating test methods.

9.4.13.15.5 The collector shall be designed to comply with all applicable requirements in this chapter.

9.4.13.15.6* The collector shall include a data plate listing the type of combustible metal dust that the material is designed to collect and a visible warning label that states collecting other materials can create a fire or explosion hazard.

9.4.13.15.6.1 The data plate on the collector shall include the following information:

(1) The metal collected by the collector
(2) The maximum P_{max} and K_{St} of dust that can be collected by the dust collector
(3) The minimum MIE of dust that can be collected by the dust collector

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

(A) If other materials are to be collected, the modified process shall first be reviewed under management of change to ensure that the requirements of this chapter are maintained.

9.4.13.15.7 Fire Protection. The requirements for fire protection for indoor dry-type dust collection systems shall apply retroactively.

9.4.13.15.7.1 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.

9.4.13.15.7.2 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.

9.4.13.15.7.3 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, *Standard on Explosion Prevention Systems.*

9.4.13.15.7.4 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 cfm).

9.4.13.15.7.5 Recirculation of exhaust air from a dry-type dust collector into the building shall be prohibited.

9.4.13.15.7.6* Media collectors shall contain a filter break detection system that automatically shuts down the collector and connected equipment if a filter break is detected.

9.4.13.15.7.7 The collector exhaust duct shall exit the building using as straight and short a path as possible.

9.4.13.15.7.8* The collector inlet duct, exhaust duct, and blower shall be inspected at least every 6 months to ensure that material is not accumulating.

9.4.13.15.7.9 The collector exhaust duct located inside the building shall use one of the following deflagration protection methods:

(1) Deflagration pressure containment in accordance with NFPA 69, *Standard on Explosion Prevention Systems*
(2)*Deflagration isolation in accordance with NFPA 69

9.4.13.15.7.10* The collector shall include a data plate listing the type of combustible metal dust that the collector is designed to collect and a visible warning label that collecting other materials can create a fire or explosion hazard.

9.4.13.15.7.11* If the material does not meet both of the following criteria, the additional requirements in 9.4.13.15.7.11 to 9.4.13.15.7.11 apply:

(1) The material is not a UN Class 4.3 solid as tested using UN 4.3 water reactivity test methods.
(2)*Water has been shown to be an effective extinguishing agent *(see Table A.6.3.3)*.

(A)* Media collectors should include automatic cleaning of filters, and the pressure drop across the filter shall be continuously monitored and alarms activate if the pressure is outside of established operating ranges.

(B) The collector shall contain a warning sign stating "This Collector Contains Combustible Metal Dust, Do not Extinguish with Water."

(C) The emergency response plan required in Section 6.4 shall include the following information to emergency responders:

(1) Location of indoor dry-type dust collectors
(2) Direction that the collector shall not be opened to extinguish a fire
(3)*Direction that a fire in the collector shall not 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

9.5* Vacuum Cleaning Systems.

9.5.1 Vacuum cleaning systems shall be used only for removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly removed by hand brushing.

9.5.2* Vacuum cleaning systems shall be bonded and grounded to minimize accumulation of static electric charge.

9.5.3 The permanently installed vacuum cleaning systems shall be in accordance with Section 9.4.

9.5.4 Due to the inherent hazards associated with the use of fixed and portable vacuum cleaning systems for finely divided combustible metal dust, special engineering consideration shall be given to the design, installation, maintenance, and use of such systems.

9.5.5 Combustible metal dust picked up by a permanently installed vacuum cleaning system shall be discharged into a container or collector located outside the building.

9.5.6* Portable Vacuum Systems.

9.5.6.1* When being used for combustible metal powders and dust, portable vacuum cleaners shall be used only if listed or approved for use with Group E dusts (combustible metal dust) and shall be identified for use with specific metals only.

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

9.5.6.3 Vacuum cleaner hose shall be conductive, and nozzles or fittings shall be made of conductive, spark-resistant material.

9.5.6.3.1 Assembled components shall be conductive and bonded, where necessary, to maintain continuity.

9.5.6.3.2 Periodic tests for continuity shall be performed.

Chapter 10 Performance-Based Design Option

10.1 General Requirements.

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

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

10.1.3* 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*, *Life Safety Code*.

10.1.3.1 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.

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

10.1.4* 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.

10.1.5 Sources of Data.

10.1.5.1 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.

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

10.2 Design Objectives.

10.2.1 Life Safety.

10.2.1.1 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 release of hazardous materials for the time needed to evacuate, relocate, or take refuge.

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

10.2.2 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 release of hazardous materials for the time necessary to evacuate, relocate, or defend in place occupants not in the immediate proximity of the ignition.

10.2.3* 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.

10.2.4 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.

10.2.4.1* 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.

10.2.4.2 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.

10.3 Performance Criteria. A system and facility design shall be deemed to meet the objectives specified in Section 10.2 if its performance meets the criteria in 10.3.1 through 10.3.5.

10.3.1 Life Safety.

10.3.1.1 The life safety objectives of 10.2.1 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.

10.3.1.2 The life safety objectives of 10.2.1 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.

10.3.1.3 The life safety objectives of 10.2.1 with respect to the release of hazardous materials that don't result in a fire or explosion shall be achieved if the following criteria are met:

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

10.3.2 Structural Integrity. The structural integrity objective of 10.2.2 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.

10.3.3 Mission Continuity. The mission continuity objectives of 10.2.3 shall be achieved when damage to equipment and the facility has been limited to a level of damage acceptable to the owner/operator.

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

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

10.3.5 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

10.4* Design Scenarios.

10.4.1 Fire Scenarios.

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

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

10.4.1.3 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.

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

10.4.1.5 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.

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

10.4.1.7 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.

10.4.2 Explosion Scenarios.

10.4.2.1 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.

10.4.2.2 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.

10.4.2.3 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.

10.4.2.4 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.

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

10.5 Evaluation of Proposed Design.

10.5.1* General. A proposed design's performance shall be assessed relative to each performance objective in Section 10.2 and each applicable scenario in Section 10.4, with the assessment conducted through the use of appropriate calculation methods acceptable to the authority having jurisdiction.

10.5.2 The design professional shall establish numerical performance criteria for each of the objectives in Section 10.2.

10.5.3 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.

10.6 Retained Prescriptive Requirements. (Reserved)

Chapter 11 Alkali Metals

11.1* General Provisions.

11.1.1 Retroactivity. The requirements of 11.1.2 through 11.1.4 shall apply to new and existing facilities.

11.1.2 Housekeeping.

11.1.2.1* Special Consideration. Alkali metals shall be kept away from sources of moisture.

11.1.3 Personal Protective Equipment (PPE). In addition to the requirements of this section, PPE shall be in accordance with Section 5.3.

11.1.3.1* PPE for Handling Solid Alkali Metals.

11.1.3.1.1 Personnel shall wear eye protection while handling solid alkali metals.

11.1.3.1.2 Personnel shall wear gloves while handling solid alkali metals.

11.1.3.1.3 Gloves shall have tight-fitting cuffs and shall be made of a material suitable for protection from caustic hazards.

11.1.3.1.4 Clothing worn by personnel handling solid alkali metals shall have no exposed pockets or cuffs that could trap and carry alkali metal residues.

11.1.3.2* PPE for Handling Molten Alkali Metals.

11.1.3.2.1 Personal protective equipment shall be worn and shall be compatible with the hazards of molten alkali metals.

11.1.3.2.2* An external clothing layer that is impervious to body moisture shall be worn for protection from splash.

11.1.4 Reactivity.

11.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g., iron oxide (rust)].

11.1.4.2 Eutectic Reactions. (Reserved)

11.1.5 Management of Change. Management of change shall be in accordance with Section 5.1.

11.1.6 Alternative Methodologies. (Reserved)

11.1.7 Test Results. (Reserved)

11.1.8 Other.

11.2* Facility Design Requirements.

11.2.1 Building Construction.

11.2.1.1 Section 11.2 shall apply to buildings or portions of buildings that are dedicated to the handling, processing, or storage of solid or molten alkali metal.

11.2.1.2 Noncombustible Materials.

11.2.1.2.1 Buildings dedicated to the storage, handling, processing, or use of alkali metals shall be constructed of noncombustible materials.

11.2.1.2.2 Construction of other than noncombustible materials shall be permitted if equivalent protection can be demonstrated.

11.2.1.3 Buildings shall comply with applicable provisions of NFPA *101, Life Safety Code.*

11.2.1.4* Roof decks shall be watertight.

11.2.1.5 Walls and ceilings shall be constructed with noncombustible insulation that has been tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C.*

11.2.1.6* In areas where alkali metals are stored, handled, or processed, floors shall be a solid surface and shall be constructed with materials that are compatible and nonreactive with alkali metals and capable of providing containment of molten alkali metals resulting from fire.

11.2.1.7* Floor drains shall not be permitted.

11.2.1.8 Where molten alkali metals are handled, dispensed, or stored, the handling area shall be provided with compatible and nonreactive containment.

11.2.1.8.1 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.

11.2.1.8.2 In areas where molten alkali metals are handled, wall-to-floor connections shall be sealed against the penetration of molten alkali metals.

11.2.1.9 Separation from Water.

11.2.1.9.1* Nonprocess piping that can contain water or steam under normal use (e.g., domestic water pipes, roof drains, waste pipes) shall not be permitted in areas containing alkali metals.

11.2.1.9.1.1 Water pipes required for safety operations shall be permitted.

11.2.1.9.1.2 Piping permitted by 11.2.1.9.1.1 shall be equipped with an emergency shutoff that is identified and located outside the area.

11.2.1.9.1.3 Piping permitted by 11.2.1.9.1.1 shall be constructed of steel.

11.2.1.9.2 A sprinkler system(s) deemed appropriate in accordance with 6.3.2 shall be permitted.

11.2.1.9.3 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.

11.2.1.9.4 The floor shall be sloped in such a manner to prevent water from entering the alkali metals area.

11.2.1.10* Ventilation.

11.2.1.10.1 Roof ventilation shall be provided for dissipation of hydrogen to the atmosphere for areas handling, processing, or storing alkali metals.

11.2.1.10.2 Mechanical ventilation systems shall be designed and installed in accordance with *NFPA 5000, Building Construction and Safety Code.*

11.2.1.11 NFPA Hazard Identification Markings.

11.2.1.11.1 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, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* to make emergency responders aware of the presence of water-reactive materials within the area.

11.2.1.11.2 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, *Standard System for the Identification of the Hazards of Materials for Emergency Response.*

11.2.2 Fire Protection.

11.2.2.1 Fire Protection. Fire protection shall be established in accordance with Chapter 6.

11.2.2.2* 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 6.

11.2.3 Dust Collection. (Reserved)

11.2.4 Hazard Analysis. The hazard analysis shall be in accordance with Section 5.2.

11.3 Primary Metal Production.

11.3.1 Reduction. (Reserved)

11.3.2 Melting and Casting.

11.3.2.1* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

11.3.2.2 Molten alkali metals shall be contained in closed systems that prevent contact with air or reactive materials, except as required for the process.

11.3.2.3 Molten alkali metal piping systems shall be designed in conformance with ANSI/ASME B31.3, *Process Piping Design*.

11.3.2.3.1 All pump seals and flange gaskets shall be made of compatible materials.

11.3.2.4 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.

11.3.2.5 Molten alkali metals shall be handled in a detached building or in portions of a building separated from other exposures by fire-rated construction.

11.3.2.6 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.

11.3.3 Refining. (Reserved)

11.4 Powder Production. (Reserved)

11.5 End Users of Powder. (Reserved)

11.6 Processing and Handling.

11.6.1 Machinery and Operations.

11.6.1.1* Where alkali metals are processed with a flammable or combustible liquid, the requirements of NFPA 30, *Flammable and Combustible Liquids Code*, shall also be followed for the flammable or combustible liquids.

11.6.1.2 Moisture Protection.

11.6.1.2.1 Solid alkali metals shall be protected from moisture during handling.

11.6.1.2.2* Mineral oils or organic materials shall not be used to protect potassium or NaK from moisture or oxygen.

11.6.1.2.3* Only the amount of alkali metal needed for an individual task or procedure shall be removed from containers.

11.6.1.2.4* Surplus alkali metal shall be placed in a container protected from moisture and sealed immediately.

11.6.1.3 Machining and Operations. (Reserved)

11.6.2 Flake and Paste. (Reserved)

11.6.3 Plasma Spray Operations. (Reserved)

11.6.4 Transfer Operations.

11.6.4.1 General Precautions.

11.6.4.1.1 Alkali metals shall be handled only by trained personnel who are knowledgeable of the hazards associated with alkali metals.

11.6.4.1.2 The number of persons in alkali metal–handling areas during operations shall be limited to those necessary for the operation.

11.6.4.1.3 Access to alkali metal–handling areas by unauthorized personnel shall not be permitted.

11.6.4.1.4* Alkali metals shall not be handled in the presence of incompatible materials.

11.6.4.1.5 Dedicated storage of ordinary combustible materials or flammable or combustible liquids shall be prohibited in areas where alkali metals are handled, processed, or stored.

11.6.4.1.5.1 Quantities of dry mineral oil necessary for safe storage and handling shall be permitted where lithium is processed, handled, or stored.

11.6.4.1.6* 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.

11.6.5 Processing Recycled Material. (Reserved)

11.7* Machining, Fabrication, Finishing, and Media Blasting.

11.7.1 Hot Work Operations.

11.7.1.1 Hot work operations shall be in accordance with Section 8.2.

11.7.2 Chip Processing. (Reserved)

11.7.3 Dust Collection. (Reserved)

11.8 Storage and Handling.

11.8.1* Storage of Product.

11.8.1.1 Alkali metals shall be handled, processed, and stored only in accordance with the requirements of this chapter.

11.8.1.2 Storage of Solid or Molten Alkali Metals.

11.8.1.2.1 General Precautions.

11.8.1.2.1.1* Alkali metals shall be permitted to be stored in shipping containers that meet the requirements of UN "Recommendations for the Transport of Dangerous Goods: Model Regulations—Manual of Tests and Criteria" for the transportation of dangerous goods for alkali metals or in clean, moisture-free, compatible, and nonreactive metal-sealed containers dedicated for the storage of alkali metals.

11.8.1.2.1.2 Alkali metals shall not be stored in containers previously used for the storage of incompatible materials.

11.8.1.2.1.3* Alkali metals shall not be stored in an area with incompatible materials.

11.8.1.2.1.4 Alkali metals in nonbulk containers shall not be stored outside.

11.8.1.3 Solid Alkali Metals Storage.

11.8.1.3.1 Solid alkali metals shall be stored only on the ground floor.

11.8.1.3.2 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.

11.8.1.3.3 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.

11.8.1.3.4 Containers shall be stored individually or on pallets in an arrangement that allows visual inspection for container integrity.

11.8.1.3.4.1 Containers on pallets shall be permitted to be stored in racks not more than 4.5 m (15 ft) high.

11.8.1.3.4.2 Containers on pallets and not stored in racks shall be stacked in a stable manner not to exceed three pallets high.

11.8.1.3.4.3 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.

11.8.1.3.4.4 Idle pallet storage shall not be permitted in alkali metal storage areas.

11.8.1.3.4.5 Idle metal pallets shall be permitted in alkali metal storage areas.

11.8.1.4 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.

11.8.2 Scrap Handling, Storage and Disposal. Alkali metals shall be handled, processed, and stored in accordance with the requirements of this chapter.

11.8.2.1 NFPA Hazard Identification Markings.

11.8.2.1.1 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, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, to make emergency responders aware of the presence of water-reactive materials within the area.

11.8.2.1.2 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, *Standard System for the Identification of the Hazards of Materials for Emergency Response.*

11.8.3 Recycling.

11.8.4 Chip Processing. (Reserved)

11.9* Fire and Explosion Protection.

11.9.1 Fire and explosion protection shall be in accordance with Chapter 6.

11.9.1.1* Alkali metal fire residues shall be stored in a designated and isolated location.

11.9.2 Housekeeping.

11.9.2.1 Dust Control. (Reserved)

11.9.2.2* Special Consideration. Alkali metals shall be kept away from sources of moisture.

11.9.3 Control of Ignition Sources.

11.9.3.1 Control of ignition sources shall be in accordance with Chapter 8.

11.9.3.2 Alkali metal fire residue containers shall be permitted to be stored outside where placed in a steel overpack drum and inspected daily.

11.9.3.2.1* Alkali metal fire residues shall be disposed of within 7 days unless the AHJ allows longer storage.

11.9.3.2.2 Alkali metal fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

11.9.3.2.3 Alkali metal fire residues shall be disposed of in accordance with federal, state, and local regulations.

11.9.3.2.4 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.

11.9.3.2.5 Alkali metal fire residues shall be stored in metal containers that are recommended by the alkali metal manufacturer.

11.9.4* Hot Work Operations.

11.9.4.1 Hotwork operations shall be in accordance with Section 8.2.

11.9.5 Control of Combustible Materials.

11.9.5.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

11.9.5.1.1 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).

11.9.5.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids.*

11.9.5.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials.*

11.9.5.2 Ordinary Combustible Storage.

11.9.5.2.1 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.

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

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

11.9.5.3.1 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.

11.9.5.3.2 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.

11.9.6 Inspection, Maintenance, and Training. (Reserved)

11.10 Other. (Reserved)

Chapter 12 Aluminum

12.1* General Provisions.

12.1.1 Retroactivity. The requirements of 12.1.3 through 12.1.8 shall apply to new and existing facilities where aluminum dusts, pastes, and/or powders are produced or handled.

12.1.1.1 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.

12.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 7.

12.1.3* Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

12.1.4 Reactivity.

12.1.4.1 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.

12.1.4.2 Contact with Water.

12.1.4.2.1* Water leakage inside or into any building where the water can contact aluminum powder shall be prevented to avoid possible spontaneous heating.

12.1.4.3 Thermite Reaction.

12.1.4.3.1* Caution shall be exercised in the mixing of aluminum fines and metal oxides [e.g., iron oxide (rust)].

12.1.4.4 Eutectic Reactions. (Reserved)

12.1.5 Alternative Methodologies. (Reserved)

12.1.6 Test Results. (Reserved)

12.1.7 Other. (Reserved)

12.1.8 Management of Change. Management of change shall be in accordance with Section 5.1.

12.2 Facility Design Requirements.

12.2.1 Building Construction.

12.2.1.1 Location of Aluminum Powder Production Plants.

12.2.1.1.1 Aluminum powder production plants 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 aluminum powder production plant.

12.2.1.1.2 A hazards analysis shall be conducted to determine the minimum separation distance for individual buildings and operations within aluminum powder production plants.

12.2.1.2 All buildings used for the manufacture, packing, or loading for shipment of aluminum powders shall be constructed of noncombustible materials throughout and shall have non-load-bearing walls.

12.2.1.3 The buildings specified in 12.2.1.2 shall be designed so that all internal surfaces are readily accessible, to facilitate cleaning.

12.2.1.4 All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where aluminum powder can infiltrate and accumulate.

12.2.1.5 The annuli of all pipe, conduit, and ventilation penetrations shall be sealed.

12.2.1.6 Floors shall be hard surfaced and shall be installed with a minimum number of joints in which aluminum powder or dust can collect.

12.2.1.7 The requirements of 12.2.1.6 shall also apply to elevated platforms, balconies, floors, and gratings.

12.2.1.8 Roofs of buildings that house combustible aluminum dust–producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

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

12.2.1.10 Where surfaces on which dust can collect are unavoidably present, they shall be covered by a smooth concrete, plaster, or noncombustible mastic fillet having a minimum slope of 55 degrees to the horizontal.

12.2.1.11 Roof decks and basements shall be watertight.

12.2.1.12 Explosion venting in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, shall be provided for buildings where aluminum powder is processed.

12.2.1.13 Deflagration venting shall not be required for areas where aluminum powder is stored or moved only in covered or sealed containers.

12.2.1.14 Door and Window Construction.

12.2.1.15 All doors in interior fire-rated partitions shall be listed self-closing fire doors, installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives*.

12.2.1.16* Emergency exits shall be provided in compliance with NFPA *101*, *Life Safety Code*.

12.2.1.17 Enclosed Passageways.

12.2.1.17.1* Where buildings or process areas are interconnected by enclosed passageways, the passageways shall be designed to prevent propagation of an explosion or fire from one unit to another in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

12.2.1.17.2 All enclosed passageways that connect with one or more processing areas shall be provided with means of egress in accordance with NFPA *101*, *Life Safety Code*.

12.2.1.18 Grounding and Lightning Protection.

12.2.1.18.1 All buildings shall be provided with a lightning protection system in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems*.

12.2.1.18.2 Lightning protection systems shall not be required for office buildings and buildings that are used for storage and handling of closed containers.

12.2.1.19 Heating and Cooling of Aluminum Powder–Production Buildings.

12.2.1.19.1 Buildings shall be permitted to be heated by indirect hot-air heating systems or by bare-pipe heating systems using steam or hot water as the heat transfer medium, or by listed electric heaters.

12.2.1.19.2 Indirect hot air shall be permitted if the heating unit is located in an adjacent room or area that is free of combustible aluminum dust.

12.2.1.19.3 Fans or blowers used to convey heated or cooled air shall be located in an area that is free of combustible aluminum dust.

12.2.1.19.4 The air supply shall be taken from outside or from a location that is free of combustible aluminum dust.

12.2.1.19.5 Makeup 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 aluminum dust or powder.

12.2.1.19.6 The requirements of 12.2.1.19.1 through 12.2.1.19.5 shall not apply to areas where aluminum metal is melted.

12.2.2 Fire Protection.

12.2.2.1 Extinguishing Agents and Application Techniques for Use on Combustible Aluminum Dusts.

12.2.2.1.1* An incipient fire shall be ringed with a dam of dry sand, dry inert granular material, or a listed Class D extinguishing powder in accordance with the manufacturer's instructions.

12.2.2.1.2 Application of dry extinguishing agent shall be conducted in such a manner as to avoid any disturbance of the combustible aluminum dust, which could cause a dust cloud.

12.2.2.1.3 The dry extinguishing agent shall be stored in such a manner that it remains clean and dry.

12.2.2.1.4* The dry extinguishing agent shall be carefully applied with a nonsparking metal scoop or shovel or applied from a listed Class D fire extinguisher.

12.2.2.1.5 Drafts shall be eliminated by shutting off fans and machinery and by closing doors and windows.

12.2.2.2 Fire Extinguishers. Portable or wheeled fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

12.2.2.2.1 Areas where dry combustible aluminum dust is present shall not have fire extinguishers rated for Class A, Class B, or Class C fires.

12.2.2.2.2 Where Class A, Class B, or Class C fire hazards are in the combustible aluminum powder area, extinguishers suitable for use on such fires shall be permitted, provided they are marked "Not for Use on Aluminum Powder Fires."

12.2.2.2.3* Extinguishers listed for use on Class B fires shall be provided in areas where solvent cleaning and washing are performed.

12.2.2.2.3.1 Conspicuous signs shall be placed adjacent to such extinguishers, stating that the extinguishers shall not be used for combustible aluminum dust fires.

12.2.2.2.3.2 Halogenated extinguishing agents shall not be used.

12.2.2.2.4* Solvent-Wetted Powders.

12.2.2.2.4.1 An incipient fire occurring while the aluminum 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.

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

12.2.2.2.5 Carbon Dioxide Use.

12.2.2.2.5.1* Where carbon dioxide is 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 other listed Class D extinguishing agent, and the entire mass shall be allowed to cool until it reaches ambient temperature.

12.2.2.2.5.2 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.

12.2.2.2.5.3* The material shall be handled in small quantities in covered containers.

12.2.2.3 Water Use. Manual water application shall be used on a solvent-metal powder fire only as a last resort, when other methods of control have failed and the fire shows evidence of burning out of control.

12.2.2.3.1 Only low-velocity spray or fog nozzles shall be used.

12.2.2.3.2 Manual application of water shall be conducted in such a manner as to avoid creating a dust cloud.

12.2.2.3.3 Once water is used, its use shall be continued until the fire is extinguished or until the area becomes untenable.

12.2.2.3.4 After extinguishment, the area shall be immediately cleaned of all wetted powder, paste, or slurry.

12.2.2.3.5 Ventilation shall be provided during cleanup to avoid concentrations of hydrogen from the exothermic reaction of the aluminum with water.

12.2.2.3.6* Fire flow containment shall not be required for existing facilities.

12.2.2.4 Automatic Sprinkler Protection.

12.2.2.4.1 Automatic sprinkler protection shall not be permitted in areas where dry aluminum powders are produced or handled.

12.2.2.4.1.1* Where both dry aluminum and other combustibles such as solvents are present, automatic sprinkler protection shall be permitted if a hazards analysis acceptable to the authority having jurisdiction indicates that automatic sprinkler systems could reduce the risk to life and damage to property.

12.2.2.4.1.2 The hazards analysis shall consider the possibility of fires and explosions involving both dry aluminum and the other combustibles.

12.2.2.4.2 The special hazards associated with aluminum powder in contact with water shall be considered in the selection, design, and installation of automatic sprinkler systems.

12.2.2.4.3 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

12.2.2.4.4 Employee training and organizational planning shall be provided to ensure safe evacuation of the sprinkler-protected area in case of fire.

12.2.2.5 Fire Fighting.

12.2.2.5.1 Incipient Fire Fighting. Facilities handling finely divided aluminum shall develop a response plan for fighting fires, in accordance with Chapter 6.

12.2.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

12.2.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

12.3 Primary Metal Production.

12.3.1 This standard shall not apply to the primary production of aluminum.

12.3.2 Melting and Casting. (Reserved)

12.3.3 Refining. (Reserved)

12.4 Aluminum Powder Production.

12.4.1 Handling and Conveying of Aluminum Powder.

12.4.1.1 Where aluminum powder is present, good housekeeping practices shall be maintained.

12.4.1.2 Aluminum powder shall be handled so as to avoid spillage and the creation of airborne dust.

12.4.1.3 Scoops, shovels, and scrapers used in the handling of aluminum powder shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

12.4.1.4 Each container for aluminum powders shall be conductive and covered while in storage or in transit.

12.4.1.5 When aluminum powders are being charged to or discharged from machines, the containers shall be bonded to the grounded machine.

12.4.1.6 When aluminum powder is being transferred between containers, the containers shall be bonded and at least one of the containers shall be grounded.

12.4.2 Portable Containers.

12.4.2.1 In-plant transport of aluminum powders shall be done in covered conductive containers as described in 12.4.1.4.

12.4.3 Ductwork for Pneumatic Conveying Systems. Ductwork for pneumatic conveying systems shall be in accordance with 9.2.1.

12.4.4 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 9.2.2.

12.4.5 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 9.3.3.

12.4.6 Powder Collection. Powder collection shall be in accordance with Section 9.4.

12.5 End Users of Powder.

12.5.1 Aluminum Powder Handling and Use.

12.5.1.1 Scope. The provisions of Section 12.5 shall apply to operations including, but not limited to, the use of aluminum powder in the production of paste, flake powders, powdered metallurgy component manufacturing, fireworks and pyrotechnics, propellants, plasma spray coating, chemical processing, and refractories.

12.5.1.2 Storage. Dry aluminum powder and aluminum paste shall be stored in accordance with the provisions of 12.8.1.

12.5.1.3* Handling. The requirements of Section 12.5 shall apply to both regular and "nondusting" grades of aluminum powder, as well as to aluminum paste.

12.5.1.4 Where aluminum powder or paste is used or handled, good housekeeping practices shall be maintained in accordance with 12.1.2.

12.5.1.5 Scoops, shovels, and scrapers used in the handling of aluminum powder and paste shall be electrically conductive and shall be grounded when necessary, and hand tools shall be made of spark-resistant materials.

12.6 Processing.

12.6.1 Machining and Operations.

12.6.1.1 Requirements for Machinery.

12.6.1.2 All combustible aluminum dust–producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

12.6.1.3* All machinery shall be bonded and grounded to minimize accumulation of static electric charge.

12.6.1.4 Bearings.

12.6.1.4.1* Ball or roller bearings shall be sealed against dust.

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

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

12.6.1.6 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.

12.6.1.7 Startup Operations. All areas of processing machinery that will be in contact with aluminum powder shall be free of foreign material and water before being placed in operation.

12.6.2 Flake and Paste.

12.6.2.1 Machinery and Operations.

12.6.2.1.1* Wet Milling of Aluminum Powder. The requirements of 12.6.2.1.1.1 through 12.6.2.1.1.6 shall not apply to machining and rolling operations.

12.6.2.1.1.1* Where aluminum 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.

12.6.2.1.1.2* Where aluminum 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.

12.6.2.1.1.3 The dew point of the atmospheres in 12.6.2.1.1.1 and 12.6.2.1.1.2 shall be maintained below the point where condensation occurs.

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

12.6.2.1.1.5* Ventilation in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, shall be maintained in areas where flammable or combustible solvents are handled, particularly in areas where combustible aluminum dusts or powders are present.

12.6.2.1.1.6 Solvent or slurry pumps shall be installed with controls that ensure that a flow exists and that the pumps run with safe operating temperatures.

12.6.3 Plasma Spray Operations.

12.6.3.1 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.

12.6.3.2 Metal overspray temperatures at the dust collector shall be compatible with the limiting temperature of the filter media element.

12.6.4 Transfer Operations.

12.6.4.1* Operations involving the transfer of combustible aluminum 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 aluminum dusts or powders.

12.6.4.2 Prevention of Fugitive Dust Accumulations. See 12.1.2.

12.6.5 Processing Recycled Material. The requirements of Chapter 19 shall apply to processes handling recycled aluminum, which is in a combustible form.

12.7* Machining, Fabrication, Finishing, and Media Blasting.

12.7.1 Hot Work Operations.

12.7.1.1 Hot work operations in facilities covered by this standard shall be in accordance with Section 8.2.

12.7.2 General Precautions.

12.7.2.1 Any equipment used for the machining, fabrication, or finishing of aluminum shall be dedicated to aluminum only and marked with a placard that reads as follows:

WARNING

Aluminum Metal Only — Fire or Explosion Can Result with Other Metals.

12.7.2.2 Equipment producing aluminum 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.

12.7.3 Chip Processing.

12.7.3.1 Machining and Sawing Operations.

12.7.3.2* Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with aluminum.

12.7.3.3* Sawing, grinding, and cutting equipment shall be grounded.

12.7.3.4 All aluminum chips, oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top containers dedicated to aluminum only and removed daily, at a minimum, to a safe storage or disposal area.

12.7.3.5 Coolant.

12.7.3.5.1* Coolants with a flash point less than 200°F shall not be used for wet grinding, cutting, or sawing operations.

12.7.3.5.2 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.

12.7.4 Dust Collection. Dust collection shall be in accordance with Chapter 9.

12.8 Storage and Handling.

12.8.1 Storage of Aluminum Powder. When aluminum powder is stored in sealed containers, the procedures of 12.8.1.1 through 12.8.1.7 shall apply.

12.8.1.1 Containers from which a portion of powder has been removed shall be carefully covered and resealed.

12.8.1.2 Containers shall be kept free of contact with water or moisture.

12.8.1.3 Aluminum 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, *Standard on Types of Building Construction*, or are of other construction types protected with an automatic sprinkler system.

12.8.1.4* Aluminum powder shall be segregated from incompatible materials and combustible materials.

12.8.1.5 When aluminum powder is stored in sealed containers, storage shall be limited to one-drum tiers per pallet with a height of no more than four pallet loads.

12.8.1.5.1 Stacked storage shall be arranged to ensure stability.

12.8.1.5.2 Aisles shall be provided for maneuverability of material-handling equipment, for ready accessibility, and to facilitate incipient fire-fighting operations.

12.8.1.6 Leakage or condensation from roof, floor, walls, drains, steam, water lines, or radiators shall be avoided.

12.8.1.7 Smoking and open flames shall be prohibited in areas where aluminum powder is stored.

12.8.2 Scrap Handling, Storage, and Disposal. (Reserved)

12.8.3 Recycling.

12.8.3.1 Where a recycling facility handles aluminum in a combustible form, the requirements of Chapter 19 shall apply.

12.8.4 Chip Processing. (Reserved)

12.9 Fire and Explosion Protection.

12.9.1 Scope. Section 12.9 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

12.9.1.1 Fire and explosion protection shall be in accordance with Chapter 6.

12.9.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 8.

12.9.3 Hot Work Operations.

12.9.3.1 Hot work operations in facilities covered by this standard shall be in accordance with Section 8.2.

12.9.4 Control of Combustible Materials.

12.9.4.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

12.9.4.1.1 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).

12.9.4.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids*.

12.9.4.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials*.

12.9.4.2 Ordinary Combustible Storage.

12.9.4.2.1 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.

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

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

12.9.4.3.1 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.

12.9.4.3.2 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.

12.9.5 Inspection, Maintenance, and Training.

12.9.5.1 Safety Inspection. 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.

12.9.5.1.1 The inspection shall be conducted at least quarterly but shall be permitted to be done more often.

12.9.5.1.2 The inspection shall be conducted by a person(s) knowledgeable in the proper practices, who shall record the findings and recommendations.

12.9.5.2* Employee Training Program. Training programs shall be instituted to inform employees about the hazards involved in the manufacture of aluminum powder, paste, or granules and the hazards involved in processing or finishing operations that generate fine combustible aluminum dust, as appropriate to the operation.

12.9.5.3 Emergency Procedures.

12.9.5.3.1 Emergency procedures to be followed in case of fire or explosion shall be established.

12.9.5.3.2* All employees shall be trained in the emergency procedures specified in 12.9.5.3.1.

12.10 Other. (Reserved)

Chapter 13 Magnesium

13.1* General Provisions.

13.1.1 Retroactivity. The requirements of 13.1.3 through 13.1.5 shall apply to new and existing facilities where magnesium dusts, pastes, and or powders are produced or handled.

13.1.1.1 In magnesium 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.

13.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 7.

13.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

13.1.4 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.

13.1.4.1 Thermite Reaction.

13.1.4.1.1* Caution shall be exercised in the mixing of magnesium fines or molten magnesium with metal oxides [e.g., iron oxide (rust)].

13.1.4.2 Eutectic Reactions. (Reserved)

13.1.5 Management of Change. Management of change shall be in accordance with Section 5.1.

13.1.6 Alternative Methodologies. (Reserved)

13.1.7 Test Results. (Reserved)

13.2 Facility Design Requirements.

13.2.1 Building Construction.

13.2.1.1 Location.

13.2.1.1.1 Magnesium powder production plants shall be located on a site large enough so that the buildings in which the powder is manufactured are at least 91.5 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 magnesium powder production plant.

13.2.1.1.2 Different production operations shall be located in separate but not adjoining buildings that are located at least 15 m (50 ft) from each other.

13.2.1.1.3 Two buildings less than 15 m (50 ft) apart shall be permitted if the facing wall of 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.

13.2.1.1.4 Separate buildings shall be required where different operations such as, but not limited to, atomization, grinding, crushing, screening, blending, or packaging are performed.

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

13.2.1.1.6 All buildings used for the manufacture, packing, or loading for shipment of magnesium powders shall be single story, shall not have basements, shall be constructed of noncombustible materials throughout, and shall have non-load-bearing walls.

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

13.2.1.1.8 Construction of other than noncombustible materials shall be permitted if equivalent protection can be demonstrated.

13.2.1.1.9 Explosion venting in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, shall be provided for buildings where magnesium powder is processed.

13.2.1.1.10 All walls or areas that are not of monolithic construction and where dust can be produced shall have all masonry joints thoroughly slushed with mortar and troweled smooth so as to leave no interior or exterior voids where magnesium powder can infiltrate and accumulate.

13.2.1.1.11* Interior surfaces where dust accumulations can occur shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulation.

13.2.1.1.12 Floors shall be of a noncombustible hard surface, nonslip, and installed with a minimum number of joints in which powder can collect.

13.2.1.1.13 The requirements of 13.2.1.1.10 shall also apply to elevated platforms, balconies, floors, and gratings.

13.2.1.1.14 Roofs of buildings that house dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect.

13.2.1.1.15 Roof decks shall be watertight.

13.2.1.1.16 Doors and Windows.

13.2.1.1.16.1 All exits shall conform to NFPA *101*, *Life Safety Code*.

13.2.1.1.16.2 All doors in fire-rated partitions shall be approved, self-closing fire doors, installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives*.

13.2.1.1.16.3* Windows shall be held in place by friction latches and shall be installed so that they open outward.

13.2.1.1.17* Grounding of Equipment. All process equipment and all building steel shall be securely grounded by permanent ground wires to prevent accumulation of static electricity.

13.2.1.1.18 Security. Paragraph 13.2.1.1.18 shall apply to new and existing magnesium powder production plants. *(See 13.1.1.)*

13.2.1.1.18.1 The intent of 13.2.1.1.18 shall be to restrict access by the general public to magnesium powder production plants and to establish adequate exits for personnel.

13.2.1.1.18.2 The powder production plant shall be surrounded by strong fencing at least 1.8 m (7 ft) high and with suitable entrance gates or shall be otherwise rendered inaccessible.

13.2.1.1.18.3 Security measures taken shall be in accordance with NFPA *101*, *Life Safety Code*.

13.2.1.1.19 Electrical Power and Control.

13.2.1.1.19.1 Electrical power and control shall be in accordance with Chapter 8.

13.2.1.1.19.2 Buildings of area less than 19 m^2 (200 ft^2) that are not normally occupied shall not be required to have emergency lighting systems.

13.2.2 Fire Protection.

13.2.3* Grounding of Equipment. All equipment shall be securely grounded by permanent ground wires to prevent accumulation of static electricity.

13.2.4 Dust Collection. Dust collection shall be in accordance with Chapter 9.

13.2.5 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

13.3 Primary Metal Production. This standard shall not apply to the primary production of magnesium.

13.3.1 Reduction.

13.3.2* Melting and Casting.

13.3.2.1 Buildings used for the melting and casting of magnesium shall be noncombustible.

13.3.2.1.1 Melt rooms shall provide access to facilitate fire control.

13.3.2.1.2* Floors shall be of noncombustible construction and shall be kept clean and free of moisture and standing water.

13.3.2.2* 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 magnesium.

13.3.2.3 Fuel supply lines to melting pots and preheating installations shall have remote fuel shutoffs and combustion safety controls in accordance with NFPA 86, *Standard for Ovens and Furnaces*, or equivalent.

13.3.2.4* Prevention of Molten Magnesium Contact with Foreign Materials.

13.3.2.4.1 Areas of furnaces that can come into contact with molten magnesium in the event of a runout shall be kept dry and free of iron oxide.

13.3.2.4.2 Crucible interiors and covers shall be maintained free of iron oxide scale, which could fall into the molten metal.

13.3.2.4.3 Molten magnesium 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.

13.3.2.4.4 Melting pots and crucibles shall be inspected regularly.

13.3.2.4.5 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.

13.3.2.5 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

13.3.2.6 Extreme care shall be exercised in pouring magnesium castings, to avoid spillage.

13.3.2.7 All molds shall be thoroughly preheated before pouring magnesium castings.

13.3.2.8 Operators in melting and casting areas shall wear flame-resistant clothing, high foundry shoes, and face protection.

13.3.2.9 Clothing worn where molten magnesium is present shall have no exposed pockets or cuffs that could trap and retain magnesium.

13.3.3 Refining. (Reserved)

13.4 Powder Production.

13.4.1 General Precautions.

13.4.1.1 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).

13.4.1.2 Water leakage within or into any building where it can contact magnesium powder shall be prevented to avoid possible spontaneous heating and hydrogen generation.

13.4.1.3 Electrical heating of any resistance element or load to a high temperature in an area containing a dust hazard shall be prohibited.

13.4.1.4* Frictional heating shall be minimized by the use of lubrication, inspection programs, and maintenance programs and by techniques recommended by the equipment manufacturer.

13.4.2 Requirements for Machinery.

13.4.2.1 All combustible magnesium dust–producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

13.4.2.2* All machinery shall be bonded and grounded to minimize the accumulation of static electric charge.

13.4.2.2.1 The requirement of 13.4.2.2 shall apply to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled.

13.4.2.2.2 Static-conductive belts shall be used on belt-driven equipment.

13.4.2.3* Only grounded and bonded bearings, properly sealed against dust, shall be used.

13.4.2.4 Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

13.4.2.5 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.

13.4.3 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.

13.4.4 Charging and Discharging.

13.4.4.1 All magnesium powder containers not used for shipping into or out of the plant shall be made of metal.

13.4.4.2 Where magnesium powders are charged to (or discharged from) machines, the containers shall be bonded to the equipment and grounded by a suitable grounding conductor.

13.4.5 Packaging and Storage.

13.4.5.1 Magnesium powder shall be stored in steel drums or other closed conductive containers.

13.4.5.2 The containers shall be tightly sealed and stored in a dry location until ready for shipment or repacking.

13.4.6 In-Plant Conveying of Magnesium Powder.

13.4.6.1 Containers.

13.4.6.1.1* In-plant transfer of powders shall be done in covered conductive containers, as described in Section 13.4.

13.4.6.1.2 Powered industrial trucks shall be selected in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, and consistent with 8.8.1.

13.4.6.1.3 All wheeled containers, hand trucks, and lift trucks shall be grounded.

13.4.7 Pneumatic Conveying. Pneumatic conveying shall be in accordance with Section 9.2.

13.4.8 Ductwork for Conveying Systems. Ductwork for conveying systems shall be in accordance with 9.2.1.

13.4.9 Fan Construction and Arrangement. Fan construction and arrangement shall be in accordance with 9.2.3.

13.4.10 Dust Collectors. Dust collectors shall be in accordance with Chapter 9.

13.5 End Users of Powder. (Reserved)

13.6 Processing.

13.6.1 Machinery and Operations. (Reserved)

13.6.2 Flake and Paste. (Reserved)

13.6.3 Plasma Spray Operations. (Reserved)

13.6.4 Transfer Operations. (Reserved)

13.6.5 Processing Recycled Material. The requirements of Chapter 19 shall apply to processes handling recycled magnesium, which is in a combustible form.

13.7* Machining, Fabrication, Finishing, and Media Blasting.

13.7.1 Hot Work Operations. Hot work operations in facilities covered by this standard shall be in accordance with Section 8.2.

13.7.2 Chip Processing.

13.7.2.1* Magnesium Chips or Powder.

13.7.2.2 Periodic cleaning of magnesium chips from buildings and machinery shall be carried out as frequently as conditions warrant.

13.7.2.3 Chips shall be removed to a safe storage or disposal area.

13.7.2.4 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

13.7.2.5 Smoking shall not be permitted in areas where ignitible magnesium chips are present.

13.7.2.5.1 Areas in which ignitible magnesium chips are present shall be posted with "No Smoking" signs.

13.7.2.5.2 Where smoking is prohibited throughout the entire plant, the use of signage shall be at the discretion of the facility management.

13.7.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

13.7.4* Machining.

13.7.4.1 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.

13.7.4.1.1 Because frictional heat can ignite any fine metal that is scraped off, the tool shall be backed off as soon as the cut is finished.

13.7.4.1.2 Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

13.7.4.2* 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.

13.7.4.3 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.

13.7.4.3.1 Side relief shall be 5 degrees.

13.7.4.3.2 End relief shall be from 10 degrees to 20 degrees.

13.7.4.4 If lubrication is needed, as in tapping or extremely fine grooving, a high–flash point lubricant shall be used.

13.7.4.4.1 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.

13.7.4.4.2 Special formulated coolant fluids (water–oil emulsions) that specifically inhibit the formation of hydrogen gas shall be permitted.

13.7.4.5 Where compressed air is used as a coolant, special precautions shall be taken to keep the air dry.

13.7.4.6 All machines shall be provided with a pan or tray to catch chips or turnings.

13.7.4.6.1 The pan or tray shall be installed such that it can be readily withdrawn from the machine in case of fire.

13.7.4.6.2 The pan shall be readily accessible for chip removal and for application of an extinguishing agent to control a fire.

13.7.4.6.3 During magnesium-machining operations, chips shall be removed from the point of generation by continuous or batch removal.

13.7.4.6.3.1 Accumulation of chips at the point of generation shall not exceed 1.4 kg (3 lb) dry weight.

13.7.4.6.3.2 All chips shall be stored in covered noncombustible containers and removed to a storage area in accordance with 13.8.1.

13.7.4.6.4 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.

13.7.5 Cleaning.

13.7.5.1 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.

13.7.5.2 Cleaning shall be done using soft brushes and conductive, nonsparking scoops and containers.

13.7.5.3* Vacuum cleaners shall not be used unless they are specifically listed for use with magnesium powder or dusts.

13.7.5.4 Machinery and equipment described in 13.4.2 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.

13.7.6* Grinding Wheels.

13.7.6.1 Wheels used for grinding magnesium castings shall be relocated for dressing.

13.7.6.2 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.

13.7.6.3 Dust collection equipment shall not have filters or other obstructions that will allow the accumulation of magnesium dust.

13.7.7 Drawing, Spinning, and Stamping.

13.7.7.1 Reliable means to prevent overheating shall be provided where magnesium is heated for drawing or spinning.

13.7.7.2 Clippings and trimmings shall be collected at frequent intervals and placed in clean, dry steel or other noncombustible containers.

13.7.7.3 Fine particles shall be handled according to the requirements of Section 13.4.

13.7.8* Heat Treating.

13.7.8.1 A standard procedure for checking the uniformity of temperatures at various points within heat-treating furnaces shall be established.

13.7.8.2 Furnaces shall be checked prior to use and at regular intervals during use to identify undesirable hot spots.

13.7.8.3* Gas- or oil-fired furnaces shall be provided with combustion safety controls.

13.7.8.4 All furnaces shall have two sets of temperature controls operating independently.

13.7.8.4.1 One set of temperature controls shall maintain the desired operating temperature.

13.7.8.4.2* 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.

13.7.8.5 Magnesium parts to be put in a heat-treating furnace shall be free of magnesium turnings, chips, and swarf.

13.7.8.6 Combustible spacers on pallets shall not be used in a heat-treating furnace.

13.7.8.7* Aluminum parts, sheets, or separators shall not be included in a furnace load of magnesium.

13.7.8.8 There shall be strict adherence to the heat-treating temperature cycle recommended by the alloy manufacturer.

13.7.8.9* Molten salt baths containing nitrates or nitrites shall not be used for heat- treating magnesium alloys.

13.7.8.10* Magnesium and aluminum metals shall be segregated and easily identified to avoid the possibility of accidental immersion of magnesium alloys in salt baths used for aluminum.

13.7.8.11* Furnaces used to heat magnesium or magnesium alloys shall be inspected and cleaned as necessary to remove any accumulation of loose iron oxide scale.

13.8 Storage and Handling.

13.8.1 Storage of Magnesium Solids.

13.8.1.1* Storage of Pigs, Ingots, and Billets.

13.8.1.1.1 The size of piles of magnesium pigs, ingots, and billets shall be limited.

13.8.1.1.1.1 Minimum aisle widths shall be based on the height of the pile per 13.8.1.1.2.4.

13.8.1.1.1.2 The pile height shall not exceed 7.1 m (20 ft).

13.8.1.1.2 Yard (Outdoor) Storage.

13.8.1.1.2.1 Magnesium ingots shall be carefully piled on firm and generally level areas to prevent tilting or toppling.

(A) Storage areas and yard pavements shall be well drained.

(B) The storage area shall be kept free of grass, weeds, and accumulations of combustible materials.

13.8.1.1.2.2 Combustible flooring or supports shall not be used under piles of ingots.

13.8.1.1.2.3 The quantity of magnesium stored in any pile shall be kept to a minimum.

(A) In no case, other than under the conditions of 13.8.1.1.2.3, shall the amount of magnesium stored exceed 45,400 kg (100,000 lb).

(B) 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.

13.8.1.1.2.4 Aisle width shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).

13.8.1.1.2.5 Readily combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium ingots.

13.8.1.1.2.6 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.

13.8.1.1.3* Indoor Storage.

13.8.1.1.3.1 Indoor storage shall be in buildings of noncombustible construction.

13.8.1.1.3.2 Floors shall be well drained to prevent accumulations of water in puddles.

13.8.1.1.3.3 Supports and pallets used under piles of magnesium ingots shall be noncombustible.

13.8.1.1.3.4 The quantity of magnesium ingots stored in any one pile shall be kept to a minimum.

(A) In no case, other than under the conditions of 13.8.1.1.3.4, shall the amount of magnesium stored exceed 23,000 kg (50,000 lb).

(B) 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)*The building is sprinklered if combustible materials are stored without the benefit of separation by fire wall or fire barrier wall from the magnesium storage.

13.8.1.1.3.5 Aisle widths shall comply with 13.8.1.1.2.4.

13.8.1.1.3.6 Combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium pigs, ingots, and billets.

13.8.1.2 Storage of Heavy Castings.

13.8.1.2.1 Except under the conditions of 13.8.1.2.2, buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

13.8.1.2.2 Storage shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system.

13.8.1.2.3* Floors shall be of noncombustible construction and shall be well drained to prevent accumulations of water in puddles.

13.8.1.2.4 All magnesium castings shall be clean and free of chips or fine particles of magnesium when being stored.

13.8.1.2.5 Storage Piles.

13.8.1.2.5.1 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).

13.8.1.2.5.2 Aisles shall be maintained to allow inspection and effective use of fire protection equipment.

13.8.1.2.6 Aisle width shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).

13.8.1.2.7* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or other packing materials are present.

13.8.1.3 Storage of Light Castings.

13.8.1.3.1 Building Construction.

13.8.1.3.1.1 Except under the conditions of 13.8.1.3.1.2, light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage by 7.7 m (25 ft).

13.8.1.3.1.2 Storage of light castings shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system. *(See 13.8.1.3.5.)*

13.8.1.3.2 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).

13.8.1.3.3 Light castings shall be segregated from other combustible materials and shall be kept away from flames or sources of heat capable of causing ignition.

13.8.1.3.4 Aisle widths shall be at least one-half the height of the piles and shall be at least 3.1 m (10 ft).

13.8.1.3.5* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

13.8.1.4 Storage in Racks or Bins.

13.8.1.4.1 Racks shall be permitted to be extended along walls in optional lengths.

13.8.1.4.2 Aisle spaces in front of racks shall be equal to the height of the racks.

13.8.1.4.3 All aisle spaces shall be kept clear.

13.8.1.4.4 Combustible rubbish, spare crates, and separators shall not be allowed to accumulate within the rack space.

13.8.1.4.5 Separators and metal sheets shall not be stacked on edge 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.

13.8.1.5 Storage of Scrap Magnesium.

13.8.1.5.1 Paragraph 13.8.1.5 shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

13.8.1.5.2 Buildings used for the indoor storage of magnesium scrap shall be of noncombustible construction.

13.8.1.5.3 Dry magnesium scraps shall be kept well separated from other combustible materials.

13.8.1.5.3.1 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.

13.8.1.5.3.2 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.

13.8.1.5.4* Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

13.8.1.5.4.1 Sources of ignition shall be kept away from the top of the container and the vent.

13.8.1.5.4.2 Containers shall not be stacked.

13.8.1.5.5 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.

13.8.1.5.6 Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers, pending salvage.

13.8.1.5.7 Oily rags, packing materials, and similar combustibles shall not be permitted in storage bins or areas that store solid magnesium scrap.

13.8.1.5.8 The use of automatic sprinklers in magnesium scrap storage buildings or areas shall be prohibited.

13.8.1.6 Storage of Magnesium Powder.

13.8.1.6.1 Buildings used to store magnesium powder shall be of noncombustible, single-story construction.

13.8.1.6.2 The use of automatic sprinklers in magnesium powder storage buildings shall be strictly prohibited.

13.8.1.6.3 Magnesium powder shall be kept well separated from other combustible or reactive metals.

13.8.1.6.4 Magnesium powder shall be stored in closed steel drums or other closed noncombustible containers, and the containers shall be stored in dry locations.

13.8.1.6.5 Magnesium powder storage areas shall be kept dry and shall be checked for water leakage.

13.8.1.6.6* Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 5.5 m (18 ft).

13.8.1.6.6.1 Storage shall be stacked in a manner that ensures stability.

13.8.1.6.6.2 Under no circumstances shall containers be allowed to topple over.

13.8.1.7 Storage of Other Magnesium Products.

13.8.1.7.1* Paragraph 13.8.1.7 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.

13.8.1.7.2 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.

13.8.1.7.3 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).

13.8.1.7.4* The storage area shall be protected by automatic sprinklers in any of the following situations:

1. Where storage in quantities greater than 28 m^3 (1000 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

13.8.2 Scrap Handling, Storage, and Disposal. (Reserved)

13.8.3 Recycling.

13.8.3.1 The requirements of Chapter 19 shall apply to processes handling recycled magnesium, which is in a combustible form.

13.8.4 Chip Processing. (Reserved)

13.9 Fire and Explosion Prevention. The provisions of Section 13.9 shall apply to all new and existing magnesium production processing, handling, and storage operations.

13.9.1 Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code*.

13.9.1.1 Fire and explosion protection shall be in accordance with Chapter 6.

13.9.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 8.

13.9.3* Hot Work.

13.9.3.1 Hot work operations shall be in accordance with Section 8.2.

13.9.3.2 Hot work permits shall be required in designated areas that contain exposed magnesium chips, powder, or sponge.

13.9.3.3 All hot work areas that require a permit shall be thoroughly cleaned of magnesium chips, powder, or sponge before hot work is performed.

13.9.4 Control of Combustible Materials.

13.9.4.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in magnesium-processing areas.

13.9.4.2 The requirement of 13.9.4.1 shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

13.9.4.3* Ordinary combustible materials shall not be discarded in containers used for the collection of magnesium sponge, chips, or powder, with the exception of floor sweepings from magnesium operations, which shall be permitted to contain small amounts of ordinary combustible materials.

13.9.5 Inspection, Maintenance, and Training.

13.9.5.1 Periodic inspections shall be conducted, as frequently as conditions warrant, to detect the accumulation of excessive magnesium chips or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

13.9.5.2 Records of the inspections specified in 13.9.5.1 shall be kept.

13.10 Other. (Reserved)

Chapter 14 Niobium

14.1* General Provisions.

14.1.1 Retroactivity. The requirements of 14.1.2 through 14.1.4 shall apply to new and existing facilities.

14.1.1.1 In niobium 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; or frictional heating or other energy sources.

14.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 7.

14.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

14.1.4 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.

14.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g. iron oxide (rust)].

14.1.4.2 Eutectic Reactions. (Reserved)

14.1.5 Management of Change. Management of change shall be in accordance with Section 5.1.

14.1.6 Alternative Methodologies. (Reserved)

14.1.7 Test Results. (Reserved)

14.1.8 Other. (Reserved)

14.2 Facility Design Requirements.

14.2.1 Building Construction.

14.2.1.1 Buildings for the storage, handling, processing, or use of niobium in a combustible form shall be constructed of noncombustible materials.

14.2.1.2 All buildings shall be of Type I or Type II construction, as defined in NFPA 220, *Standard on Types of Building Construction.*

14.2.1.3 Floors in niobium facilities shall be made of noncombustible materials.

14.2.1.3.1* A hazards analysis shall be completed to determine where static-dissipative flooring or static-dissipative floor mats shall be required in niobium powder–manufacturing facilities storing, handling, processing, or using niobium in a combustible form.

14.2.1.3.2 The hazards analysis shall specifically consider the combustibility and specific character of the materials being handled in the facility.

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

14.2.1.5 Roof decks shall be watertight.

14.2.1.6 Drying Room Construction.

14.2.1.6.1 Drying rooms shall be of Type I construction as defined by NFPA 220, *Standard on Types of Building Construction.*

14.2.1.6.2 Drying rooms shall be segregated as far as is practical from other operations.

14.2.1.6.3 A hazards analysis shall be performed to determine whether deflagration venting is needed in drying rooms.

14.2.1.6.4 A hazards analysis shall be performed to determine the proper type of drying used for the specific niobium powders being handled as well as the specific parameters used for drying.

14.2.1.6.5 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, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls.*

14.2.1.6.6 Openings in fire walls and fire barrier walls shall be protected in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives.*

14.2.1.6.7 All penetrations of floors, walls, ceilings, or partitions shall be dusttight, and where structural assemblies have a fire resistance rating, the seal shall maintain that rating.

14.2.1.6.8 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.

14.2.1.6.9* 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 be permitted where a hazards analysis is performed by a person who is knowledgeable in the hazards of niobium and is acceptable to the authority having jurisdiction.

14.2.1.7 Grounding of Equipment.

14.2.1.7.1 All permanently installed process equipment and all building structural steel shall be bonded and grounded by permanent ground wires to prevent accumulation of static electricity.

14.2.1.7.2* Movable or mobile process equipment of metal construction shall be bonded and grounded prior to use.

14.2.1.7.3* A periodic monitoring and testing schedule acceptable to the authority having jurisdiction shall be established to ensure that the effectiveness of grounding and bonding of fixed and mobile equipment has not failed or deteriorated over time and use.

14.2.1.7.4 Where dry niobium powders are charged to or discharged from equipment, the containers shall be bonded or grounded.

14.2.1.7.5 Only conductive containers shall be used for the processing of niobium powders.

14.2.1.7.6 When dry niobium powder is transferred between containers, the containers shall be bonded and grounded.

14.2.1.8 Explosion Mitigation/Venting.

14.2.1.8.1 Fittings used on compressed air, water, nitrogen, and inert gas–line outlets shall be distinguishable, to prevent potential explosions caused by inadvertent use of the wrong material.

14.2.1.8.2* Where a room or building contains a dust explosion hazard external to protected equipment, such areas shall be evaluated for the application of deflagration venting.

14.2.1.8.3* 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.

14.2.1.8.4* Relief valves shall not be vented to a dust hazard area.

14.2.1.8.5 Equipment shall be located or arranged in a manner that minimizes combustible dust accumulations on surfaces.

14.2.2 Fire Protection.

14.2.2.1 Extinguishing Agents and Application Techniques for Use in Combustible Niobium Dusts.

14.2.2.2 Fire Extinguishers. (Reserved)

14.2.2.3 Automatic Sprinkler Protection. (Reserved)

14.2.2.4 Fire Fighting.

14.2.2.4.1 Incipient Fire Fighting. Facilities handling finely divided aluminum shall develop a response plan for fighting fires in accordance with Chapter 6.

14.2.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

14.2.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

14.3 Primary Metal Production

14.3.1 Reduction. (Reserved)

14.3.2 Melting and Casting. (Reserved)

14.3.3 Refining. (Reserved)

14.3.4* Explosion Prevention.

14.3.4.1* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

14.3.4.2 Sealed vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the vessel.

14.3.4.2.1* Water-cooled furnaces shall have the crucible and its water jacket located in a protective noncombustible enclosure that provides a means of isolation to protect personnel and to minimize damage to adjacent structures and equipment if an explosion occurs.

14.3.4.2.2 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.

14.3.5 Upper Chamber of the Furnace.

14.3.5.1* The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.

14.3.5.2 Means shall be provided to prevent the influx of air through the pressure-relief port.

14.3.5.3 Large low-pressure ports shall not be used.

14.3.5.4* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

14.3.5.5* The furnace shall be equipped with a device that continuously senses pressure within the furnace.

14.3.5.5.1 The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

14.3.5.5.2 The furnace shall be equipped with the following:

(1) Waterflow, temperature, and pressure sensors on all cooling systems
(2) Arc voltage recorders and melting power recorders
(3) Electrode position indicators
(4) Furnace pressure sensors and recorders
(5) Set point alarms on critical process systems to warn of abnormal conditions

14.3.5.5.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

14.3.5.6* Water-cooled crucibles shall be inspected to ensure that minimum wall thicknesses are maintained to prevent a breach of the crucible wall.

14.3.6* Water Supply.

14.3.6.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source upon a drop in water pressure or waterflow.

14.3.6.2 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.

14.3.6.3 Equipment construction shall mitigate the potential for ignition of the niobium powder.

14.3.6.4 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

14.3.6.5 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

14.3.7 Casting.

14.3.7.1 Water Supply.

14.3.7.1.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source upon a drop in water pressure or waterflow.

14.3.7.1.2 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.

14.3.7.2* Molds.

14.3.7.2.1 Molds for niobium casting shall be made of material that is compatible with molten niobium.

14.3.7.2.2 Molds shall be dried thoroughly and shall be stored to prevent accumulation of moisture in the molds.

14.3.7.2.3 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.

14.3.7.2.4* Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

14.3.7.3* Residue.

14.3.7.3.1 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.

14.3.7.3.2 The containers specified in 14.3.7.3.1 shall be stored so that any hydrogen gas generated vents freely.

14.3.8 Personnel Safety Precautions.

14.3.8.1 Molten niobium shall be contained in closed systems that prevent its unintentional contact with air or reactive materials.

14.3.8.2 Personnel involved in niobium melting operations with the potential for exposure to molten niobium shall wear appropriate PPE.

14.3.8.3 Niobium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium.

14.3.9* Machining Operations and Fabrication Operations.

14.3.9.1* Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of niobium.

14.3.9.2 All machines shall be provided with a pan or tray to catch chips or turnings.

14.3.9.2.1 The pan or tray shall be installed so that it is accessible for chip, turning, or compacted niobium powder removal and for application of an extinguishing agent to control a fire.

14.3.9.2.2 The pan construction shall be sufficient to minimize the potential for burn-through.

14.3.9.2.3 In case of fire in the chips, turnings, or compacted niobium powder, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of niobium, until the fire has been extinguished and the material has cooled to ambient temperature.

14.3.9.2.4* Cutting tools shall be designed for use with niobium and shall be kept sharp.

14.3.9.2.5* 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).

14.3.9.2.6* Flammable or combustible liquids shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

14.3.9.2.7 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

14.3.9.2.8 The coolant shall be filtered on a continuous basis, and the collected solids shall not be permitted to accumulate in quantities greater than 19 L (5 gal).

14.3.9.2.9 The collected solids shall be moved to a designated storage or disposal area.

14.3.9.2.10 Crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily to a designated storage or disposal area.

14.3.9.2.11 Where fully dense forms of niobium metal are conditioned via grinding or sanding operations, consideration shall be given to ensure that the residual dusts produced are handled in a safe fashion.

14.3.9.2.12 A hazards analysis shall be conducted to ensure that these operations do not contribute to fugitive dust accumulation.

14.3.9.2.13 If dust collection is used for grinding and sanding applications, take-up hoods shall be designed to minimize the accumulation of dust.

14.3.10 Hot Work. Refer to 14.9.3.

14.4 Niobium Powder Production for Primary Producers.

14.4.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for ignition of the niobium.

14.4.2* Only niobium powder for immediate use shall be present in handling areas.

14.4.2.1 Daily supplies of niobium powder shall be allowed to be stored in the production area.

14.4.2.1.1 The niobium powder shall be stored in covered containers and shall be segregated from other combustible materials.

14.4.2.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

14.4.2.1.3 The containers shall be protected from damage.

14.4.3 Transport of dry niobium powders within manufacturing operations and storage of dry niobium powders within manufacturing areas shall be done in covered conductive containers.

14.4.4 Powered industrial trucks shall be selected in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, and consistent with 8.8.1.

14.4.5 To minimize the risk of fire or explosion hazard in the handling of niobium powders, the equipment and process shall be designed by persons experienced and knowledgeable in the hazards of niobium powders.

14.4.6 Drying of Niobium Powder. A hazards analysis acceptable to the authority having jurisdiction shall be conducted to determine appropriate methods and parameters for drying of niobium powder based on the specific materials being handled and dried.

14.4.6.1* Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

14.4.6.2 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 80°C (176°F).

14.4.6.3* When drying niobium powders under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the niobium shall be cooled to less than 80°C (176°F) prior to exposure to air.

14.4.6.4 Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.

14.4.6.5 Dry inert gas atmosphere shall be permitted to be recycled to the drying process if passed through a filter, a dust collector, or equivalent means of dust removal capable of removing 95 percent of the suspended particulate.

14.4.7* Dryers.

14.4.7.1 Dryers shall be constructed of noncombustible materials.

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

14.4.7.3* Products of combustion, as a result of a collector fire, shall be considered when designing wet collector installations.

14.4.7.4 Wet collectors posing a significant fire and evacuation risk shall have their exhaust air conveyed directly to the exterior of the building.

14.4.7.5 Explosion protection shall be provided as specified in 14.4.5.

14.4.7.6* 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.

14.4.7.7 Heated dryers shall have operating controls configured to maintain the temperature of the drying chamber within the prescribed limits.

14.4.7.8 Excess temperature–limit controls required in 14.4.7.6 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

14.4.8 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 14.4.7.8.

14.4.9 Heated dryers and their auxiliary equipment shall be equipped 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

14.4.10 All automatic shutdowns required by 14.4.8 shall require manual reset before the dryer can be returned to operation.

14.4.11 If the niobium powder being dried has been determined, via test requirements in Chapter 4 of this standard, to be combustible, only dryers specifically determined by their manufacturers to be safe for drying combustible materials shall be allowed to be used.

14.4.12 Powder Production.

14.4.12.1* Where niobium powder is present, good housekeeping practices shall be maintained.

14.4.12.2 A hazards analysis acceptable to the authority having jurisdiction shall be conducted to determine that powder-handling practices are suitable for the specific powders being used.

14.4.12.3 Niobium powder shall be handled so as to avoid spillage and the creation of airborne dust.

14.4.12.4* Scoops, shovels, and scrapers used in the handling of dry niobium powder shall be electrically conductive and shall be bonded or grounded.

14.4.12.5 Hand tools used in handling dry niobium powder shall be made of spark-resistant materials.

14.4.12.6 Care shall be exercised to avoid the presence of an isolated conductor in the vicinity of niobium powder being handled.

14.4.12.7* The use of humidifiers in facilities where dry niobium powder is handled shall be considered.

14.4.12.8 Sintering furnaces that handle niobium parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces*.

14.4.12.9 Niobium powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

14.4.12.10 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

14.4.13 Electrical Installations.

14.4.14 Explosion Prevention and Protection.

14.4.14.1* Explosion Risk Evaluation and Explosion Suppression Design. A documented risk evaluation acceptable to the authority having jurisdiction shall be conducted 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 niobium being handled.

14.4.14.2 Where explosion protection is required per 14.4.14.1, 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, *Standard on Explosion Prevention Systems*
(4) Inert gas used to reduce the oxygen content within the equipment to below the level prescribed by NFPA 69, *Standard on Explosion Prevention Systems*
(5)*Inert gas used to reduce the oxygen content within the equipment to below 50 percent of the LOC for the specific form of the material being processed
(6) Oxidant concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

14.4.14.3 If the method specified in 14.4.14.2(5) is used, test data for the specific dust and dilution combinations shall be provided and shall be acceptable to the authority having jurisdiction.

14.4.14.4 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.

14.4.14.5 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.

14.4.15* Inerting. A supply of argon or helium as an inerting agent shall be provided on site at all times for blanketing and purging equipment.

14.4.16 Personnel Safety Precautions.

14.4.16.1* Personnel handling niobium powder shall wear static-dissipative footwear and flame-resistant clothing that are designed to minimize the accumulation of niobium 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.

14.4.16.2 Personnel handling niobium 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.

14.4.16.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

14.4.16.4* Niobium powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium powder.

14.4.16.5 Access to niobium powder–handling areas by unauthorized personnel shall not be permitted.

14.5 End Users of Niobium Powder.

14.5.1 Equipment shall be constructed to mitigate the potential for ignition of niobium powder.

14.5.2 A hazards analysis shall be performed for areas where niobium powder is present to determine risk factors and applicable controls.

14.5.3 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.

14.5.4* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of niobium powder.

14.5.5* Spark-resistant tools shall be used.

14.5.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

14.5.7* Niobium Powder Storage.

14.5.7.1 Niobium powder–handling areas or niobium powder–processing areas shall not be used for primary storage of niobium.

14.5.7.1.1 Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in niobium-processing areas.

14.5.7.2 Stacked Storage.

14.5.7.2.1 Where niobium powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

14.5.7.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

14.5.7.3 Dry Niobium Powder Handling.

14.5.7.3.1 Precautions shall be taken to prevent spills or dispersions that produce niobium dust clouds.

14.5.7.3.2 Sintering furnaces that handle compacted niobium powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces*.

14.5.7.3.2.1 Niobium powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

14.5.7.3.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

14.5.7.4 Wet Niobium Powder Handling. Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

14.5.7.4.1 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).

14.5.7.4.2 When drying niobium powders under controlled atmospheric conditions (for example, vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the niobium shall be cooled to less than 80°C (176°F) prior to exposure to air.

14.5.7.5 Heat Treatment and Passivation.

14.5.7.5.1 General.

14.5.7.5.1.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of niobium.

14.5.7.5.1.2 Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54, *National Fuel Gas Code*.

14.5.7.5.1.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces*.

14.5.7.6 Personnel Safety Precautions.

14.5.7.6.1 Niobium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium.

14.5.7.6.2 Access to niobium-handling areas by unauthorized personnel shall not be permitted.

14.5.7.6.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

14.5.7.7 Niobium Powder Heat Treatment and Sintering.

14.5.7.7.1 After niobium powder furnacing, the niobium powder shall be passivated prior to exposure to air atmosphere.

14.5.7.7.2 Furnaced niobium powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

14.5.7.7.3 Furnaced niobium powder shall be monitored during passivation to ensure that uncontrolled oxidation, resulting in unacceptable temperature increase of the niobium, does not occur.

14.5.7.8* Heat Treatment and Sintering of Niobium Compacts.

14.5.7.8.1 Sintered niobium compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

14.5.7.8.2 Sintered niobium compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

14.5.7.9 Safety Precautions.

14.5.7.9.1 If the furnace primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cooldown time period.

14.5.7.9.2 The alternative cooling system specified in 14.5.7.9.1 shall be activated automatically on failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

14.6 Processing and Handling.

14.6.1 Machinery and Operations. (Reserved)

14.6.2 Flake and Paste. (Reserved)

14.6.3 Plasma Spray Operations. (Reserved)

14.6.4 Transfer Operations. (Reserved)

14.6.5 Processing Recycled Material. (Reserved)

14.7* Machining, Fabrication, Finishing, and Media Blasting.

14.7.1 Hot Work Operations. See 14.9.3.

14.7.2 Chip Processing. (Reserved)

14.7.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

14.8 Storage and Handling.

14.8.1 Storage of Product.

14.8.1.1 Storage with Incompatible Materials. Niobium shall not be stored in an area with incompatible materials.

14.8.1.2 Scrap Storage.

14.8.1.2.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

14.8.1.2.2 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.

14.8.1.3 Powder Storage.

14.8.1.3.1* Niobium powder shall be stored in covered containers.

14.8.1.3.2 Niobium storage areas shall be free of combustible goods (other than the container used to store the niobium) and plainly marked with “No Open Flame” signs.

14.8.1.3.3 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.

14.8.1.3.4 Under no circumstances shall stack height exceed 3.1 m (10 ft).

14.8.1.3.5 Stacked storage shall be arranged to ensure stability.

14.8.1.3.6 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

14.8.1.4 Other Production Materials.

14.8.1.4.1 Magnesium Operations. All magnesium storage, handling, and processing operations in niobium production operations shall be in accordance with the requirements of Chapter 13.

14.8.1.4.2 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

14.8.2 Scrap Handling, Storage, and Disposal. Scrap handling, storage, and disposal shall be in accordance with Chapter 19.

14.8.3 Recycling. Recycling shall be in accordance with Chapter 19.

14.8.4 Chip Processing. (Reserved)

14.9 Fire and Explosion Protection.

14.9.1 Fire and explosion protection shall be in accordance with Chapter 6.

14.9.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 8.

14.9.3* Hot Work Operations. Hot work, exclusive of process activities, shall not be permitted in areas where combustible forms of niobium are present until exposed equipment has been cleaned thoroughly.

14.9.4 Control of Combustible Material.

14.9.4.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code*.

14.9.4.1.1 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).

14.9.4.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids.*

14.9.4.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials.*

14.9.4.2 Ordinary Combustible Storage.

14.9.4.2.1 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.

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

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

14.9.4.3.1 All combustible metal chips, lathe turnings, and swarf shall be collected in closed-top metal containers and removed a minimum of once daily, to a safe storage or disposal area.

14.9.4.3.2 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.

14.9.5 Inspection, Maintenance, and Testing. (Reserved)

14.10 Other. (Reserved)

Chapter 15 Tantalum

15.1* General Provisions.

15.1.1 Retroactivity. The requirements of 15.1.2 through 15.1.4 shall apply to new and existing facilities where tantalum dusts, pastes, and/or powders are produced or handled.

15.1.1.1 In tantalum 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.

15.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 7.

15.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

15.1.4 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.

15.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of fines or molten material with metal oxides [e.g., iron oxide (rust)].

15.1.4.2 Eutectic Reactions. (Reserved)

15.1.5 Management of Change. Management of change shall be in accordance with Section 5.1.

15.1.6 Alternative Methodologies. (Reserved)

15.1.7 Test Results. (Reserved)

15.1.8 Other. (Reserved)

15.2 Facility Design Requirements.

15.2.1 Building Construction.

15.2.1.1 Buildings for the storage, handling, processing, or use of tantalum in a combustible form shall be constructed of noncombustible materials.

15.2.1.2 All buildings shall be of Type I or Type II construction, as defined in NFPA 220, *Standard on Types of Building Construction.*

15.2.1.3 Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes.

15.2.1.4 Floors.

15.2.1.4.1 Floors in facilities shall be made of noncombustible materials.

15.2.1.4.2 A hazards analysis shall be completed to determine where static-dissipative flooring or static-dissipative floor mats shall be required in tantalum powder–manufacturing facilities. *(See Annex B.)*

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

15.2.1.6 Roof decks shall be watertight.

15.2.1.7 Drying Rooms.

15.2.1.7.1 Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction.*

15.2.1.7.2 Drying rooms shall be segregated as far as practicable from other operations.

15.2.1.8 A hazards analysis shall be performed to determine whether deflagration venting is needed in drying rooms.

15.2.1.9 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, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls.*

15.2.1.10 Openings in fire walls and fire barrier walls shall be protected by self-closing fire doors having a fire resistance rating equivalent to the wall design. Fire doors shall be installed according to NFPA 80, *Standard for Fire Doors and Other Opening Protectives.*

15.2.1.11 All penetrations of floors, walls, ceilings, or partitions shall be dusttight, and where structural assemblies have a fire resistance rating, the seal shall maintain that rating.

15.2.1.12 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.

15.2.1.13 Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code.*

15.2.1.14* 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 be permitted where a hazards analysis is performed by a person who is knowledgeable in the hazards of tantalum and is acceptable to the authority having jurisdiction.

15.2.1.15 Grounding of Equipment.

15.2.1.15.1 Where dry tantalum powders are charged to or discharged from equipment, the containers shall be bonded and grounded.

15.2.1.15.2 When dry tantalum powder is transferred between containers, the containers shall be bonded and grounded.

15.2.1.16 Explosion Mitigation and Venting.

15.2.1.16.1 Fittings used on compressed air, water, nitrogen, and inert gas–line outlets shall be distinguishable in order to prevent potential explosions caused by inadvertent use of the wrong material.

15.2.1.16.2* Deflagration Venting.

15.2.1.16.2.1* Where a room or building contains a dust explosion hazard external to protected equipment, such areas shall be evaluated for the application of deflagration venting requirements in accordance with good engineering practice.

15.2.1.16.2.2* 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.

15.2.1.17 Relief valves shall not be vented to a dust hazard area.

15.2.1.18* Equipment shall be located or arranged in a manner that minimizes combustible dust accumulations on surfaces.

15.2.2 Fire Protection.

15.2.2.1 Extinguishing Agents and Application Techniques for Use on Combustible Tantalum Dusts.

15.2.2.1.1* An incipient fire shall be ringed with a dam of dry sand, dry inert granular material, or a listed Class D extinguishing powder in accordance with the manufacturer's instructions.

15.2.2.1.2 Application of dry extinguishing agent shall be conducted in such a manner as to avoid any disturbance of the combustible tantalum dust, which could cause a dust cloud.

15.2.2.1.3 The dry extinguishing agent shall be stored in such a manner that it remains clean and dry.

15.2.2.1.4* The dry extinguishing agent shall be carefully applied with a nonsparking metal scoop or shovel or applied from a listed Class D fire extinguisher.

15.2.2.1.5 Drafts shall be eliminated by shutting off fans and machinery and by closing doors and windows.

15.2.2.2 Fire Extinguishers. Portable or wheeled fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers.*

15.2.2.3 Areas where dry combustible tantalum dust is present shall not have fire extinguishers rated for Class A, Class B, or Class C fires.

15.2.2.4 Where Class A, Class B, or Class C fire hazards are in the combustible tantalum powder area, extinguishers suitable for use on such fires shall be permitted, provided they are marked "Not for Use on Tantalum Powder Fires."

15.2.2.5* Extinguishers listed for use on Class B fires shall be provided in areas where solvent cleaning and washing are performed.

15.2.2.5.1 Conspicuous signs shall be placed adjacent to such extinguishers, stating that the extinguishers shall not be used for combustible tantalum dust fires.

15.2.2.5.2 Halogenated extinguishing agents shall not be used.

15.2.2.6 Automatic Sprinkler Protection.

15.2.2.6.1 Automatic sprinkler protection shall not be permitted in areas where dry tantalum powders are produced or handled.

15.2.2.6.1.1* Where both dry tantalum and other combustibles such as solvents are present, automatic sprinkler protection shall be permitted if a hazards analysis acceptable to the authority having jurisdiction indicates that automatic sprinkler systems could reduce the risk to life and damage to property.

15.2.2.6.1.2 The hazards analysis shall consider the possibility of fires and explosions involving both dry tantalum and the other combustibles.

15.2.2.6.2 The special hazards associated with tantalum powder in contact with water shall be considered in the selection, design, and installation of automatic sprinkler systems.

15.2.2.6.3 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems.*

15.2.2.6.4 Employee training and organizational planning shall be provided to ensure safe evacuation of the sprinkler-protected area in case of fire.

15.2.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

15.2.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

15.3 Primary Metal Production.

15.3.1 Reduction. (Reserved)

15.3.2 Melting and Casting Operations for Primary Producers.

15.3.2.1* Explosion Prevention.

15.3.2.1.1* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

15.3.2.1.2 Sealed vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the vessel.

15.3.2.1.3* Water-cooled furnaces shall have the crucible and its water jacket located in a protective noncombustible enclosure that provides a means of isolation, to protect personnel and to minimize damage to adjacent structures and equipment if an explosion occurs.

15.3.2.1.4 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.

15.3.2.2* Upper Chamber of the Furnace.

15.3.2.2.1 The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.

15.3.2.2.2 Means shall be provided to prevent the influx of air through the pressure-relief port.

15.3.2.2.3 The release pressure of the pressure-relief device shall be a gauge pressure of 138 kPa (20 psi) maximum.

15.3.2.2.4 Large low-pressure ports shall not be used.

15.3.2.3* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

15.3.2.4 Pressure-Sensing Device.

15.3.2.4.1 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

15.3.2.4.2* The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

15.3.2.5* The furnace shall be equipped with the following:

(1) Waterflow, temperature, and pressure sensors on all cooling systems
(2) Arc voltage recorders and melting power recorders
(3) Electrode position indicators
(4) Furnace pressure sensors and recorders
(5) Set point alarms on critical process systems to warn of abnormal conditions

15.3.2.6 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

15.3.2.7 Water Supply.

15.3.2.7.1 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.

15.3.2.7.2 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.

15.3.2.8 Equipment construction shall mitigate the potential for ignition of the tantalum powder.

15.3.2.9 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

15.3.2.10 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

15.3.2.11 Casting.

15.3.2.11.1 Water Supply.

15.3.2.11.2* 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.

15.3.2.11.3 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.

15.3.2.12 Molds.

15.3.2.12.1 Molds for tantalum casting shall be made of material that is compatible with molten tantalum.

15.3.2.12.2* Molds shall be dried thoroughly and shall be stored to prevent accumulation of moisture in the molds.

15.3.2.12.3 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.

15.3.2.13* Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

15.3.2.14 Residue.

15.3.2.14.1* 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.

15.3.2.14.2 The containers specified in 15.3.2.14.1 shall be stored so that any hydrogen gas generated vents freely.

15.3.2.15 Personnel Safety Precautions for Melting Operations.

15.3.2.15.1 Molten tantalum shall be contained in closed systems that prevent its unintentional contact with air or reactive materials.

15.3.2.15.2 Tantalum metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum.

15.3.3 Refining. (Reserved)

15.4 Powder Production.

15.4.1 Drying and Storage of Tantalum Powder.

15.4.1.1* Water-wetted powder, when air-dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

15.4.1.2 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 80°C (176°F).

15.4.1.3 When tantalum powders are dried under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the tantalum shall be cooled to less than 80°C (176°F) prior to exposure to air.

15.4.1.4* Dryers.

15.4.1.4.1 Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.

15.4.1.4.2 Dry inert gas atmosphere shall be permitted to be recycled to the drying process if passed through a filter, dust collector, or equivalent means of dust removal capable of removing 95 percent of the suspended particulate.

15.4.1.4.3 Dryers shall be constructed of noncombustible materials.

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

15.4.1.4.5 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.

15.4.1.4.6 Explosion protection shall be provided as specified in 15.4.2.9.

15.4.1.4.7 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.

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

15.4.1.4.9 Heated dryers and their auxiliary equipment shall be equipped 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

15.4.1.4.10* Excess temperature–limit controls required in 15.4.1.4.9 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

15.4.1.4.11 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 15.4.1.4.10.

15.4.1.4.12 All automatic shutdowns required by 15.4.1.4.10 shall require manual reset before the dryer can be returned to operation.

15.4.2 Tantalum Powder Handling (for Primary Producers).

15.4.2.1 Equipment shall be constructed to mitigate the potential for ignition of tantalum.

15.4.2.2* Only tantalum powder for immediate use shall be present in handling areas.

15.4.2.2.1 Tantalum powder–handling or tantalum powder–processing areas shall not be used for primary storage of tantalum.

15.4.2.2.2 Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in tantalum-processing areas.

15.4.2.3 Transport of dry tantalum powders within manufacturing operations and storage of dry tantalum powders within manufacturing areas shall be done in covered conductive containers.

15.4.2.4 Where tantalum powder is present, good housekeeping practices shall be maintained.

15.4.2.5 Tantalum powder shall be handled so as to avoid spillage and the creation of airborne dust.

15.4.2.6 Scoops, shovels, and scrapers used in the handling of dry tantalum powder shall be electrically conductive and shall be bonded and grounded.

15.4.2.7 Hand tools used in handling dry tantalum powder shall be made of spark-resistant materials.

15.4.2.8* Sintering furnaces that handle tantalum parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces.*

15.4.2.8.1 Tantalum powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

15.4.2.8.2 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

15.4.2.9 Explosion Prevention and Protection.

15.4.2.9.1* A documented risk evaluation acceptable to the authority having jurisdiction shall be conducted to determine the level of explosion protection to be provided for the process.

15.4.2.9.2 Where explosion protection is required per 15.4.2.9.1, one or more of the following methods shall be used:

(1) Equipment designed to contain the anticipated explosion pressure
(2)*Appropriately designed explosion venting
(3) Explosion suppression system meeting the requirements of NFPA 69, *Standard on Explosion Prevention Systems*
(4) Inert gas used to reduce the oxygen content within the equipment to below the level prescribed by NFPA 69, *Standard on Explosion Prevention Systems*
(5)*Dilution with a noncombustible dust to render the mixture noncombustible
(6) Oxidant concentration reduction in accordance with NFPA 69, *Standard on Explosion Prevention Systems*

15.4.2.9.3 If the method specified in 15.4.2.9.2(5) is used, test data for specific dust and dilution combinations shall be provided and shall be acceptable to the authority having jurisdiction.

15.4.2.9.4 Recirculating comfort air shall be permitted to be returned to the work area where tests conducted by an approved testing organization prove the collector's efficiency is great enough to provide 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. Systems shall be periodically inspected and maintained to ensure proper operation.

15.4.2.10* Inerting. A supply of argon or helium, as an inerting agent, shall be provided on-site at all times for blanketing and purging equipment.

15.4.2.11 Personnel Safety Precautions.

15.4.2.11.1* Personnel handling tantalum powder shall wear static-dissipative footwear and flame-resistant clothing that are designed to minimize the accumulation of tantalum powder.

15.4.2.11.2 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

15.4.2.11.3 Tantalum powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum powder.

15.4.2.11.4* Access to tantalum powder–handling areas by unauthorized personnel shall not be permitted.

15.5 End Users of Powder.

15.5.1 General.

15.5.1.1* Equipment shall be constructed to mitigate the potential for ignition of tantalum powder.

15.5.1.2 A hazards analysis shall be performed for areas where tantalum powder is present to determine risk factors and appropriate controls.

15.5.1.3* 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.

15.5.1.4* Where static-dissipative flooring or static-dissipative floor mats are required, personnel shall wear flame-resistant clothing designed to minimize the accumulation of tantalum powder.

15.5.1.5* Spark-resistant tools shall be used.

15.5.1.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

15.5.2 Tantalum Powder Storage.

15.5.2.1 Daily supplies of tantalum powder shall be allowed to be stored in the production area.

15.5.2.1.1 The tantalum powder shall be stored in covered containers and shall be segregated from other combustible materials.

15.5.2.1.2 The maximum capacity of the container shall be such that it can be moved by available equipment.

15.5.2.1.3 The containers shall be protected from damage.

15.5.2.2 Stacked Storage.

15.5.2.2.1 When storing tantalum powder in sealed containers, stacked storage shall be arranged to ensure stability.

15.5.2.2.2 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

15.5.3 Dry Tantalum Powder Handling.

15.5.3.1* Precautions shall be taken to prevent spills or dispersions that produce tantalum dust clouds.

15.5.3.2 Sintering furnaces that handle compacted tantalum powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces.*

15.5.3.2.1 Tantalum powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

15.5.3.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

15.5.4 Wet Tantalum Powder Handling by End Users.

15.5.4.1* Water-wetted powder, when air-dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

15.5.4.2 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 80°C (176°F).

15.5.4.3 When tantalum powders are dried under controlled atmospheric conditions (e.g., vacuum or inert atmosphere) and the temperature exceeds 80°C (176°F), the tantalum shall be cooled to less than 80°C (176°F) prior to exposure to air.

15.5.5 Heat Treatment and Passivation.

15.5.5.1 General.

15.5.5.1.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of tantalum.

15.5.5.1.2 Fuel supply lines to gas-fired furnaces or other gas-fired equipment shall be installed and maintained in accordance with NFPA 54, *National Fuel Gas Code.*

15.5.5.1.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

15.5.6* Personnel Safety Precautions.

15.5.6.1 Tantalum metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum.

15.5.6.2 Access to tantalum-handling areas by unauthorized personnel shall not be permitted.

15.5.6.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

15.5.7 Tantalum Powder Heat Treatment and Sintering.

15.5.7.1 After tantalum powder furnacing, the tantalum powder shall be passivated prior to exposure to air atmosphere.

15.5.7.2 Furnaced tantalum powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

15.5.8* Heat Treatment and Sintering of Tantalum Compacts.

15.5.8.1* Sintered tantalum compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

15.5.8.2 Sintered tantalum compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

15.5.9 Safety Precautions.

15.5.9.1 If the furnace primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cooldown time period.

15.5.9.2 The alternative cooling system specified in 15.5.9.1 shall be activated automatically upon failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

15.6 Processing and Handling. (Reserved)

15.6.1 Machinery and Operations. (Reserved)

15.6.2 Flake and Paste. (Reserved)

15.6.3 Plasma Spray Operations. (Reserved)

15.6.4 Transfer Operations. (Reserved)

15.6.5 Processing Recycled Material. (Reserved)

15.7* Machining, Fabrication, Finishing, and Media Blasting.

15.7.1* Hot Work. Hot work such as electric arc or gas torch welding shall not be permitted in areas where combustible forms of tantalum are present and until exposed equipment has been cleaned thoroughly. *(See Section 8.2 for additional requirements.)*

15.7.2 Chip Processing. (Reserved)

15.7.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

15.7.4 Machining Operations.

15.7.4.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of tantalum.

15.7.4.2 All machines shall be provided with a pan or tray to catch chips or turnings.

15.7.4.2.1* The pan or tray shall be installed so that it is accessible for removal of chips, turnings, or compacted tantalum powder and for application of an extinguishing agent to control a fire.

15.7.4.2.2 The pan construction shall be sufficient to minimize the potential for burn-through.

15.7.4.2.3 The cleaned air shall be permitted to be returned to the work area when tests conducted by an approved testing organization prove that the collector's efficiency is great enough to provide safety to both personnel and property safety in the particular installation, with regard to particulate matter in the cleaned air and accumulations or particulate matter and hydrogen in the work area.

15.7.4.2.4 The use of additional dry filter media downstream of a wet collector shall not be permitted.

15.7.4.2.5 The discharge duct for all dust collection equipment shall terminate at a safe outdoor location except where permitted by 15.7.4.2.3.

15.7.4.3 In the case of fire in the chips, turnings, or compacted tantalum powder, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of tantalum, until the fire has been extinguished and the material has cooled to ambient temperature.

15.7.4.4* Cutting tools shall be designed for use with tantalum and shall be kept sharp.

15.7.4.5* 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).

15.7.4.6 Flammable or combustible liquids shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

15.7.4.7 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

15.7.4.7.1 The coolant shall be filtered on a continuous basis, and the collected solids shall not be permitted to accumulate in quantities greater than 19 L (5 gal).

15.7.4.7.2 The collected solids shall be moved to a designated storage or disposal area.

15.7.4.8* Crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily to a designated storage or disposal area.

15.7.5 In-Plant Conveying of Tantalum Powder.

15.7.5.1 Enclosed Mechanical Conveyors.

15.7.5.1.1 Housings for enclosed conveyors (e.g., screw and drag conveyors) shall be of metal construction and shall be designed to prevent escape of tantalum powders.

15.7.5.1.2 Coverings on clean-out, inspection, and other openings shall be closed and fastened.

15.7.5.1.3* Screw conveyors and bucket elevators that agitate the tantalum being transported shall be enclosed in dusttight casings and shall be equipped with explosion prevention or protection methods in accordance with 15.4.2.9.

15.7.5.1.4 Power Shutoff.

15.7.5.1.4.1 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.

15.7.5.1.4.2 Feed to the conveyor shall be stopped or diverted.

15.7.5.2 Pneumatic Conveying.

15.7.5.2.1 Pneumatic systems shall be designed in accordance with NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids.*

15.7.5.2.2 Power Shutoff.

15.7.5.2.2.1 All pneumatic 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.

15.7.5.2.2.2 Feed to the conveyor shall be stopped or diverted.

15.7.5.2.3* The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

15.7.5.3 Ductwork for Conveying Systems. Ductwork for conveying systems shall be in accordance with 9.2.1.

15.7.5.4 Fan Construction and Arrangement. Fan construction and arrangement shall be in accordance with 9.2.3.

15.8 Storage and Handling.

15.8.1 Storage of Product.

15.8.1.1 Storage of Incompatible Materials. Tantalum shall not be stored in an area with incompatible materials.

15.8.1.2 Sponge Storage. (Reserved)

15.8.1.3 Powder Storage.

15.8.1.3.1* Tantalum powder shall be stored in covered containers.

15.8.1.3.2 Tantalum storage areas shall be free of combustible goods (other than the container used to store the tantalum), well ventilated, equipped with the required fire protection equipment, and plainly marked with "No Open Flame" signs.

15.8.1.3.3 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 remove a stack and no stack shall exceed 3.1 m (10 ft) in height.

15.8.1.3.4 Stacked storage shall be arranged to ensure stability.

15.8.1.3.5 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

15.8.1.4 Storage of Other Production Materials Associated with Tantalum.

15.8.1.4.1 Magnesium Operations. All magnesium storage, handling, and processing operations in tantalum production operations shall be in accordance with the requirements of Chapter 13.

15.8.1.4.2 Sodium Operations. All sodium storage, handling, and processing operations shall be in accordance with Chapter 11.

15.8.1.4.3 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

15.8.2 Scrap Handling, Storage, and Disposal.

15.8.2.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

15.8.2.2 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.

15.8.3 Recycling. (Reserved)

15.8.4 Chip Processing. (Reserved)

15.9 Fire and Explosion Prevention. The provisions of Section 15.9 shall apply to all new and existing tantalum powder production processes, handling, and storage operations.

15.9.1 Fire and explosion prevention shall be in accordance with Chapter 6.

15.9.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 8.

15.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 8.2.

15.9.4 Control of Combustible Materials.

15.9.4.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in tantalum-processing areas.

15.9.4.2 Where ordinary combustible materials are necessary for the process and are stored in designated areas, 15.9.4.1 shall not apply.

15.9.4.3 Ordinary combustible materials shall not be discarded in containers used for the collection of chips or powder.

15.9.4.4 Floor sweepings from tantalum operations shall be permitted to contain small amounts of ordinary combustible materials and shall be stored in separate containers.

15.9.4.5 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

15.9.4.6 Where tantalum 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 available.

15.9.5 Inspection, Maintenance, and Testing.

15.9.5.1 Periodic inspections shall be conducted as frequently as conditions warrant to detect the accumulation of excessive tantalum chips or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

15.9.5.2 Records of the inspections specified in 15.9.5.1 shall be kept.

15.10 Other. (Reserved)

Chapter 16 Titanium

16.1* General Provisions.

16.1.1 Retroactivity. The requirements of 16.1.2 through 16.1.5 shall apply to new and existing facilities.

16.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 7.

16.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

16.1.4 Reactivity.

16.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of titanium fines and metal oxides [e.g., iron oxide (rust)].

16.1.4.2* Eutectic Reactions. It shall be the responsibility of the facility to research processing and materials for potentially dangerous reactions and eutectic compositions, which could occur in the course of their activities.

16.1.5* Management of Change. Management of change shall be in accordance with Section 5.1.

16.1.6 Alternative Methodologies. (Reserved)

16.1.7 Test Results. (Reserved)

16.1.8 Other. (Reserved)

16.2 Facility Design Requirements.

16.2.1 Building Construction.

16.2.1.1 Individuals or firms not previously knowledgeable in designing facilities and/or equipment for the processing of titanium shall be briefed by individual(s) or firm(s) knowledgeable in the specific hazards associated with handling, processing, and storage and this standard.

16.2.1.2 Buildings housing furnaces, boring and crushing facilities, and titanium refining operations shall be constructed of noncombustible materials.

16.2.1.3 Buildings shall comply with the applicable provisions of NFPA *101, Life Safety Code.*

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

16.2.1.5 All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where dust can infiltrate and accumulate.

16.2.1.6 Explosion venting, if provided, shall be in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting.*

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

16.2.1.8 Titanium winning, refining, and casting operations shall be protected from rain and from other possibilities of inadvertent contact with water.

16.2.1.9 Permanent water lines in the winning, refining, and casting operations area shall be of all-metal construction.

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

16.2.1.11 Emergency shutoff valves shall be clearly identified.

16.2.1.12 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

16.2.1.13 Drying rooms (for titanium powder) shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*.

16.2.1.13.1 Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

16.2.1.13.2 An analysis shall be performed to determine whether drying rooms require deflagration venting.

16.2.2 Fire Protection.

16.2.2.1 The provisions of Section 16.2 shall apply to all new and existing titanium production, processing, handling, and storage operations.

16.2.2.2 See Chapter 6 for additional information.

16.2.2.3 Equipment used for the processing of titanium shall be bonded and grounded.

16.2.2.4 Tanks in which flammable or combustible solvents are used for degreasing shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

16.2.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

16.2.4 Hazard Analysis. The hazard analysis shall be in accordance with Section 5.2.

16.3 Primary Metal Production.

16.3.1 Reduction.

16.3.1.1 Reactor vessels shall be air-cooled.

16.3.1.2 Sealed titanium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

16.3.1.3 All containers used to receive molten magnesium, molten titanium, or molten titanium chloride shall be cleaned and dried thoroughly before use.

16.3.1.4 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than 1814 kg (4000 lb).

16.3.1.5 Combustible materials shall be minimized in the (sponge) collection area, well-ventilated and free from other materials.

16.3.1.6 Dust resulting from the crushing of titanium sponge shall be managed safely to minimize the risk of fires and explosions.

16.3.2 Melting and Casting.

16.3.2.1 General Provisions.

16.3.2.1.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the furnace upon a drop in water pressure or water flow.

16.3.2.1.2 An emergency source of cooling water shall be provided for crucibles and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

16.3.2.1.3 The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in safely relieving pressure if water enters the furnace.

16.3.2.1.4 Means shall be provided to prevent the influx of air through the pressure-relief port.

16.3.2.1.5 The release pressure of the rupture disc shall be at a gauge pressure of 138 kPa (20 psi) maximum.

16.3.2.1.6 Large low-pressure ports shall not be used.

16.3.2.1.7 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

16.3.2.1.8 The device shall automatically interrupt power to the melting heat source in the event of an expected sharp rise in pressure.

16.3.2.1.9 The furnace shall be equipped with the following:

(1) Water flow, temperature, and pressure sensors on all cooling systems
(2) Furnace pressure sensors and recorders
(3) Set point alarms on all systems to warn of abnormal conditions

16.3.2.1.10 The casting chamber shall be cooled or shall be sufficiently massive to accommodate a spill, or both, since mold breaks are inevitable.

16.3.2.1.11 Iron scale and metal spillage shall be minimized in furnaces.

16.3.2.1.12 All furnace pits and bunkers shall be evaluated as confined spaces.

16.3.2.2 Molds and Crucibles.

16.3.2.2.1 Molds (and crucibles) for titanium casting (melting) shall be made of material that is compatible with molten titanium.

16.3.2.2.2 Molds (and crucibles) shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

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

16.3.2.3 Vacuum Arc Remelt (VAR) and Electroslag Remelting (ESR).

16.3.2.3.1 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.

16.3.2.3.2 A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

16.3.2.3.3 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

16.3.2.3.4 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

16.3.2.4 Electron Beam (EB) and Plasma Arc Melting (PAM). (Reserved)

16.3.2.5 Vacuum Induction Melting (VIM) and Skull. (Reserved)

16.3.3 Refining. (Reserved)

16.4 Powder Production.

16.4.1 Drying and Storage.

16.4.1.1 Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

16.4.1.2 Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*.

16.4.1.3 Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

16.4.1.4 An analysis shall be performed to determine whether drying rooms require deflagration venting.

16.4.1.5 Titanium powder shall be stored in sealed containers in well-ventilated areas.

16.4.1.6 The containers shall be kept free of combustibles.

16.4.1.7 The containers shall be protected from damage.

16.4.2 Titanium Powder Handling.

16.4.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

16.4.2.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

16.4.2.3 Hot zones of furnaces that handle titanium in any form shall be provided with inert atmospheres or vacuum.

16.4.2.4 The furnaces shall be designed in accordance with NFPA 86, *Standard for Ovens and Furnaces*, and shall be of spark-proof construction and good engineering practice.

16.4.2.5 To minimize the risk of fire or explosion hazards in the handling of dry titanium powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of titanium powder.

16.4.2.6 Only nonsparking tools and utensils shall be used in handling titanium powder.

16.5 End Users of Powders. (Reserved)

16.6 Processing and Handling.

16.6.1 Machinery and Operations. (Reserved)

16.6.2 Flake and Paste. (Reserved)

16.6.3 Plasma Spray Operations. (Reserved)

16.6.4 Transfer Operations. (Reserved)

16.6.5 Processing Recycled Material. (Reserved)

16.7* Machining, Fabrication, Finishing, and Media Blasting.

16.7.1 Hot Work Operations. All hot work operations shall be in accordance with Section 8.2 in addition to the requirements of this section.

16.7.1.1 Fabrication processes that use electric arcs or open flames or that create sparks shall not be permitted within 10.7 m (35 ft) of any area where titanium chips, fines, dust, or any combustible materials are produced, handled, packaged, or stored.

16.7.1.2 All welding of titanium shall be carried out under an inert atmosphere, such as helium or argon, or under vacuum.

16.7.1.3 The facility shall have a review system prior to any hot work (to include, but not be limited to, welding, grinding, or cutting operations, which might ignite titanium fines) being performed.

16.7.2 Chip Processing.

16.7.2.1 Machining.

16.7.2.1.1 Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with titanium.

16.7.2.1.2 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

16.7.2.1.3 The coolant shall be filtered on a continuous basis, and the collected solids shall not be permitted to accumulate in quantities greater than 19 L (5 gal) and shall be moved to a safe storage or disposal area.

16.7.2.1.4 Operations in which titanium is subjected to processing or finishing shall include, but shall not be limited to grinding, buffing, polishing, sawing, and machining of solids.

16.7.2.1.5 Mill operations shall cover the forging and finishing of titanium products in a primary production facility.

16.7.3 Dust Collection. See 16.2.3.

16.7.4 Processing.

16.7.4.1 Furnaces or other equipment used for heating titanium shall be cleaned to minimize the presence of iron scale or residue that could react exothermically with the metal being heated.

16.8 Storage and Handling.

16.8.1 Storage of Product.

16.8.1.1 Magnesium for use in the sponge producing process shall be stored in accordance with Chapter 13.

16.8.1.2 Chlorine shall be handled and stored in accordance with accepted industry practice.

16.8.1.3 Bulk containers of liquid titanium tetrachloride ($TiCl_4$) shall be stored in a well-ventilated place located away from areas of acute fire hazard. Containers shall be identified plainly and sealed tightly until used.

16.8.1.4 General Storage.

16.8.1.4.1 Titanium storage areas shall be kept free of combustible materials, shall be well-ventilated, shall be equipped with required fire protection equipment as specified in Section 16.9, and shall be plainly marked with “No Smoking” signs.

16.8.1.4.2 Where titanium 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.

16.8.1.4.3 Where drums are used, storage shall be limited to one-drum tiers per pallet, with a height of not more than four pallet loads.

16.8.1.4.4 Stacked storage shall be positioned in such a manner as to ensure stability.

16.8.1.4.5 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

16.8.1.4.6 The maximum weight of material (per pallet or container) shall be capable of being moved by the available equipment.

16.8.1.4.7 Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

16.8.1.4.8 Storage of materials in closed noncombustible containers shall be permitted.

16.8.1.5 Sponge Storage.

16.8.1.5.1 Titanium sponge shall be stored in closed metal containers.

16.8.1.5.2 Containers shall not be sealed unless they are inerted.

16.8.1.5.3 Storage of sponge shall comply with 16.8.1.4.

16.8.1.5.4 Sealed titanium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

16.8.2 Scrap Handling, Storage, and Disposal.

16.8.2.1 Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

16.8.2.2 Covered, vented steel containers shall be used to transport collected sludge (from wet dust collectors) to a safe storage area or for disposal.

16.8.2.3 Sludge shall be disposed of in accordance with local, state, and federal regulations.

16.8.3 Recycling. Recycling shall be in accordance with Chapter 19.

16.8.4 Chip Processing. (Reserved)

16.9 Fire and Explosion Prevention.

16.9.1 Fire and explosion prevention shall comply with Chapter 6.

16.9.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 8.

16.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 8.2.

16.9.4 Control of Combustible Materials.

16.9.4.1 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

16.9.4.1.1 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).

16.9.4.1.2 Dipping and coating applications of flammable or combustible liquids shall be done in accordance with NFPA 34, *Standard for Dipping, Coating, and Printing Processes Using Flammable or Combustible Liquids.*

16.9.4.1.3 Spray application of flammable or combustible liquids shall be done in accordance with NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials.*

16.9.4.2 Ordinary Combustible Storage.

16.9.4.2.1 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.

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

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

16.9.4.3.1 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.

16.9.4.3.2 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.

16.9.5 Inspection, Maintenance, and Training.

16.9.5.1 Regular inspections shall be conducted to detect the accumulation of excessive titanium dust, chips, or fines on any portions of buildings or machinery not regularly cleaned in daily operations.

16.9.5.2 Records shall be kept of the inspections conducted in 16.9.5.1.

16.10 Other. (Reserved)

Chapter 17 Zirconium and Hafnium

17.1* General Provisions.

17.1.1 Retroactivity. The requirements of 17.1.2 through 17.1.5 shall apply to new and existing facilities.

17.1.2 Housekeeping. Housekeeping shall be in accordance with Chapter 7.

17.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

17.1.4 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 its operations.

17.1.4.1* Thermite Reactions. Caution shall be exercised in the mixing of zirconium or hafnium fines or molten material with metal oxides [e.g., iron oxide (rust)].

17.1.4.2 Eutectic Reactions.

17.1.4.2.1* It shall be the responsibility of the facility to research processing and materials for potentially dangerous reactions and eutectic compositions, which could occur in the course of their activities.

17.1.5 Management of Change. Management of change shall be in accordance with Section 5.1.

17.1.6 Alternative Methodologies. (Reserved)

17.1.7 Test Results. (Reserved)

17.1.8 Other. (Reserved)

17.2 Facility Design Requirements.

17.2.1 Building Construction.

17.2.1.1 Individuals or firms not previously knowledgeable in designing facilities and/or equipment for the processing of zirconium or hafnium shall be briefed by individual(s) or firm(s) knowledgeable in the specific hazards associated with handling, processing, and storage and this standard.

17.2.1.2 Buildings housing furnaces, boring and crushing facilities, and zirconium or hafnium refining operations shall be constructed of noncombustible materials.

17.2.1.3 Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code*.

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

17.2.1.5 All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where dust can infiltrate and accumulate.

17.2.1.6 Explosion venting, if provided, shall be in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

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

17.2.1.8 Zirconium or hafnium winning, refining, and casting operations shall be protected from rain and from other possibilities of inadvertent contact with water.

17.2.1.9 Permanent water lines in the winning, refining, and casting operations area shall be of all-metal construction.

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

17.2.1.11 Emergency shutoff valves shall be clearly identified.

17.2.1.12 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

17.2.1.13 Drying rooms (for zirconium or hafnium powder) shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*.

17.2.1.13.1 Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

17.2.1.13.2 An analysis shall be performed to determine whether drying rooms require deflagration venting.

17.2.1.14 Flash-Fire and Explosion Hazard Protection. (Reserved)

17.2.2 Fire Protection.

17.2.2.1 The provisions of 17.2.2 shall apply to all new and existing zirconium or hafnium production, processing, handling, and storage operations.

17.2.2.2 See Chapter 6 for additional information.

17.2.2.3 Equipment used for the processing of zirconium or hafnium shall be bonded and grounded.

17.2.2.4 Tanks in which flammable or combustible solvents are used for degreasing shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

17.2.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

17.2.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

17.3 Primary Metal Production.

17.3.1 Reduction.

17.3.1.1 Reactor vessels shall be air-cooled.

17.3.1.2 Sealed zirconium or hafnium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

17.3.1.3 All containers used to receive molten magnesium, molten zirconium or hafnium, or molten zirconium or hafnium chloride 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 1814 kg (4000 lb).

17.3.1.5 Zirconium or hafnium storage areas shall be kept free of combustible materials, shall be well ventilated, shall be equipped with the required fire protection equipment, and shall be plainly marked with “No Smoking” signs.

17.3.1.6 Dust resulting from the crushing of zirconium or hafnium sponge shall be managed safely to minimize the risk of fires and explosions.

17.3.2 Melting and Casting.

17.3.2.1 General Provisions.

17.3.2.1.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the furnace upon a drop in water pressure or water flow.

17.3.2.1.2 An emergency source of cooling water shall be provided for crucibles and shall be actuated automatically by flow interlock in the event of interruption of the primary cooling water.

17.3.2.1.3 The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in safely relieving pressure if water enters the furnace.

17.3.2.1.4 Means shall be provided to prevent the influx of air through the pressure-relief port.

17.3.2.1.5 The release pressure of the rupture disc shall be at a gauge pressure of 138 kPa (20 psi) maximum.

17.3.2.1.6 Large low-pressure ports shall not be used.

17.3.2.1.7 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

17.3.2.1.8 The device shall automatically interrupt power to the melting heat source in the event of an expected sharp rise in pressure.

17.3.2.1.9 The furnace shall be equipped with the following equipment:

(1) Water flow, temperature, and pressure sensors on all cooling systems

(2) Furnace pressure sensors and recorders
(3) Set point alarms on all systems to warn of abnormal conditions

17.3.2.1.10 The casting chamber shall be cooled or shall be sufficiently massive to accommodate a spill, or both, since mold breaks are inevitable.

17.3.2.1.11 Iron scale and metal spillage shall be minimized in furnaces.

17.3.2.1.12 All furnace pits and bunkers shall be evaluated as confined spaces.

17.3.2.2 Molds and Crucibles.

17.3.2.2.1 Molds (and crucibles) for zirconium or hafnium casting (melting) shall be made of material that is compatible with molten zirconium or hafnium.

17.3.2.2.2 Molds (and crucibles) shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

17.3.2.2.3 All pieces of zirconium or hafnium metal shall be clean and dry when charged to reactors.

17.3.2.3 Vacuum Arc Remelt (VAR) and Electroslag Remelting (ESR).

17.3.2.3.1 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.

17.3.2.3.2 A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

17.3.2.3.3 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

17.3.2.3.4 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

17.3.2.4 Electron Beam (EB) and Plasma Arc Melting (PAM). (Reserved)

17.3.2.5 Vacuum Induced Melting (VIM) and Skull. (Reserved)

17.3.3 Refining. (Reserved)

17.4 Powder Production.

17.4.1 Drying and Storage.

17.4.1.1 Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

17.4.1.2 Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*.

17.4.1.3 Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

17.4.1.4 An analysis shall be performed to determine whether drying rooms require deflagration venting.

17.4.1.5 Zirconium or hafnium powder shall be stored in sealed containers in well-ventilated areas.

17.4.1.6 The containers shall be kept free of combustibles.

17.4.1.7 The containers shall be protected from damage.

17.4.2 Zirconium or Hafnium Powder Handling.

17.4.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

17.4.2.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

17.4.2.3 Hot zones of furnaces that handle zirconium or hafnium in any form shall be provided with inert atmospheres or vacuum.

17.4.2.4 The furnaces shall be designed in accordance with NFPA 86, *Standard for Ovens and Furnaces*, and shall be of sparkproof construction and good engineering practice.

17.4.2.5 To minimize the risk of fire or explosion hazards in the handling of dry zirconium or hafnium powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of zirconium or hafnium powder.

17.4.2.6 Only nonsparking tools and utensils shall be used in handling zirconium or hafnium powder.

17.5 End Users of Powders. (Reserved)

17.6 Processing and Handling. (Reserved)

17.6.1 Machinery and Operations. (Reserved)

17.6.2 Flake and Paste. (Reserved)

17.6.3 Plasma Spray Operations. (Reserved)

17.6.4 Transfer Operations. (Reserved)

17.6.5 Processing Recycled Material. (Reserved)

17.7* Machining, Fabrication, Finishing, and Media Blasting.

17.7.1 Hot Work Operations. Hot work operations shall be in accordance with Section 8.2.

17.7.2 Chip Processing.

17.7.2.1 Machining.

17.7.2.1.1 Cutting tools shall be of proper design and shall be kept sharp for satisfactory work with zirconium or hafnium.

17.7.2.1.2 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

17.7.2.1.3 The coolant shall be filtered on a continuous basis, and the collected solids shall not be permitted to accumulate in quantities greater than 19 L (5 gal) and shall be moved to a safe storage or disposal area.

17.7.2.1.4 Operations in which zirconium or hafnium is subjected to processing or finishing shall include, but shall not be limited to grinding, buffing, polishing, sawing and machining of solids.

17.7.2.1.5 Mill operations shall cover the forging and finishing of zirconium or hafnium products in a primary production facility.

17.7.3 Dust Collection. See Chapter 9.

17.7.4 Processing.

17.7.4.1 Furnaces or other equipment used for heating zirconium or hafnium shall be cleaned to minimize the presence of iron scale or residue that could react exothermically with the metal being heated.

17.8 Storage and Handling.

17.8.1 Storage of Product.

17.8.1.1 Magnesium for use in the sponge producing process shall be stored in accordance with Chapter 13.

17.8.1.2 Chlorine shall be handled and stored in accordance with accepted industry practice.

17.8.1.3 Bulk containers of liquid zirconium tetrachloride ($ZrCl_4$) or hafnium or hafnium tetrachloride ($HfCl_4$) shall be stored in a well-ventilated place located away from areas of acute fire hazard. Containers shall be identified plainly and sealed tightly until used.

17.8.1.4 General Storage.

17.8.1.4.1 Zirconium or hafnium storage areas shall be kept free of combustible materials, shall be well-ventilated, shall be equipped with required fire protection equipment as specified in Section 17.9, and shall be plainly marked with "No Smoking" signs.

17.8.1.4.2 Where zirconium or hafnium 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.

17.8.1.4.3 Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of not more than four pallet loads.

17.8.1.4.4 Stacked storage shall be positioned in such a manner as to ensure stability.

17.8.1.4.5 Aisles shall be provided for maneuverability of material-handling equipment, for accessibility, and to facilitate fire-fighting operations.

17.8.1.4.6 The maximum weight of material (per pallet or container) shall be capable of being moved by the available equipment.

17.8.1.4.7 Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

17.8.1.4.8 Storage of materials in closed noncombustible containers shall be permitted except as noted for sponge. *(See 17.8.1.5.2.)*

17.8.1.5 Sponge Storage.

17.8.1.5.1 Zirconium or hafnium sponge shall be stored in closed metal containers.

17.8.1.5.2 Containers shall not be sealed unless they are inerted.

17.8.1.5.3 Storage of sponge shall comply with 17.8.1.4.

17.8.1.5.4 Sealed zirconium or hafnium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

17.8.2 Scrap Handling, Storage, and Disposal.

17.8.2.1 Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

17.8.2.2 Covered, vented steel containers shall be used to transport collected sludge (from wet dust collectors) to a safe storage area or for disposal.

17.8.2.3 Sludge shall be disposed of in accordance with local, state, and federal regulations.

17.8.3 Recycling. Recycling shall be in accordance with Chapter 19.

17.8.4 Chip Processing. (Reserved)

17.9 Fire and Explosion Prevention.

17.9.1 The requirements of Chapter 6 shall apply.

17.9.2 Control of Ignition Sources. Control of ignition sources shall be in accordance with Chapter 8.

17.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 8.2.

17.9.4 Control of Combustible Materials. (Reserved)

17.9.5 Inspection, Maintenance, and Training.

17.9.5.1 Regular inspections shall be conducted to detect the accumulation of excessive zirconium or hafnium dust, chips, or fines on any portions of buildings or machinery not regularly cleaned in daily operations.

17.9.5.2 Records shall be kept of the inspections conducted in 17.9.5.1.

17.10 Other. (Reserved)

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 7.

18.1.3 Personal Protective Equipment (PPE). PPE shall be in accordance with Section 5.3.

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 5.1.

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 Building Construction.

18.2.1.1 Buildings housing combustible metals operations shall be of noncombustible construction, unless a hazard analysis has been performed that shows that noncombustible construction is not required.

18.2.1.2 Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code*.

18.2.1.3 Building areas where combustible metal dusts might be present shall be designed so that all internal surfaces are accessible, to facilitate cleaning.

18.2.1.3.1 All walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where dust can infiltrate and accumulate.

18.2.1.3.2 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

18.2.1.4 Roofs.

18.2.1.4.1 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.

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

18.2.1.5 Floors, elevated platforms, balconies, and gratings shall be hard surfaced and installed with a minimum number of joints in which powder or dust can collect.

18.2.1.6* Explosion venting in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, 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.

18.2.1.7 All doors in interior fire-rated partitions shall be listed, self-closing fire doors installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives*.

18.2.1.8 Buildings or portions of buildings of noncombustible construction used principally for combustible-metal storage or handling shall not be permitted to be equipped with automatic sprinkler protection.

18.2.1.9 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, 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.

18.2.1.10 Fittings used on outlets of compressed-air and inert-gas lines shall not be interchangeable, to prevent potential explosions caused by inadvertently using compressed air in place of low-pressure inert gas.

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

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

18.2.1.13 Enclosed Passageways.

18.2.1.13.1 Where buildings or process areas are interconnected by enclosed passageways, the passageways shall be designed in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, to prevent propagation of an explosion or fire from one unit to another.

18.2.1.13.2 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 NFPA *101*, *Life Safety Code*.

18.2.1.14 Heating and Cooling of Buildings.

18.2.1.14.1 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.

18.2.1.14.2 Indirect hot air shall be permitted if the heating unit is located in a combustible metal dust–free area adjacent to the room or area where heated air is required.

18.2.1.14.3 Fans or blowers used to convey the heated or cooled air shall be located in a combustible metal dust–free location.

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

18.2.1.14.5 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.

18.2.1.14.6 The requirements of 18.2.1.14.1 through 18.2.1.14.5 shall not apply to areas where metal is melted.

18.2.2 Fire Protection. Fire protection shall be in accordance with Chapter 6.

18.2.3 Dust Collection. Dust collection shall be in accordance with Chapter 9.

18.2.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

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 over-temperature 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, *Standard for Ovens and Furnaces*.

18.3.2.7 Fuel supply lines shall comply with NFPA 54, *National Fuel Gas Code*.

18.3.2.8 Use of flammable and combustible liquids shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

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. Dustwork for pneumatic conveying systems shall be in accordance with 9.2.1.

18.4.4 Conveying Using an Inert Medium. Conveying using an inert medium shall be in accordance with 9.2.2.

18.4.5 Fan and Blower Construction and Arrangement. Fan and blower construction and arrangement shall be in accordance with 9.2.3.

18.4.6 Powder Collection. Powder collection shall be in accordance with Section 9.3.

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 7.

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, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations*, and consistent with 18.2.1.

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, *Standard for Ovens and Furnaces.*

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, *National Fuel Gas Code.*

18.5.6.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

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, *Flammable and Combustible Liquids Code*, 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 of *NFPA 70, National Electrical Code*, with the exception of control equipment meeting the requirements of NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment.*

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 8.2.

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 9.

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 15.

18.9.2 Control of Ignition Sources. (Reserved)

18.9.3 Hot Work Operations. Hot work operations shall be in accordance with Section 8.2.

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 15.

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 10 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 18.2.1.

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 4 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; re-melt 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 5.3.

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 5.1.

19.8 Facility Design Requirements.

19.8.1 Building Construction.

19.8.1.1 Location of Recycling and Waste Management Facilities.

19.8.1.1.1 A hazards analysis shall be conducted to determine the minimum separation distance for individual buildings and operations within recycling and waste management plants.

19.8.1.2 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.

19.8.1.3 Where dust is present, the buildings specified in 19.8.1.2 shall be designed so that all internal surfaces are readily accessible, to facilitate cleaning.

19.8.1.4 Where dust is present, all walls of areas where fugitive dust can be produced shall have a smooth finish and shall be sealed so as to leave no interior or exterior voids where combustible metal dust can infiltrate and accumulate.

19.8.1.5 The annuli of all pipe, conduit, and ventilation penetrations shall be sealed.

19.8.1.6 Floors shall be hard surfaced and shall be installed with a minimum number of joints in which metal dust can collect.

19.8.1.7 The requirements of 19.8.1.4 shall also apply to elevated platforms, balconies, floors, and gratings.

19.8.1.8 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.

19.8.1.9* Interior surfaces where combustible metal dust accumulations can occur shall be designed and constructed to facilitate cleaning and to minimize combustible dust accumulations.

19.8.1.10 Where surfaces on which combustible metal dust can collect are unavoidably present, they shall be covered by a smooth concrete, plaster, or noncombustible mastic fillet having a minimum slope of 55 degrees to the horizontal.

19.8.1.11 Roof decks and basements shall be watertight.

19.8.1.12 Explosion venting in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, shall be provided for buildings where metal powders are processed.

19.8.1.13 Deflagration venting shall not be required for areas where combustible metals are stored or moved only in covered or sealed containers.

19.8.1.14 Door and Window Construction.

19.8.1.14.1 All doors in interior fire-rated partitions shall be listed self-closing fire doors, installed in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives.*

19.8.1.14.2* Emergency exits shall be provided in compliance with NFPA *101, Life Safety Code.*

19.8.1.15 Enclosed Passageways.

19.8.1.15.1 Where buildings or process areas are interconnected by enclosed passageways, the passageways shall be designed to prevent propagation of an explosion or fire from one unit to another in accordance with NFPA 68, *Standard on Explosion Protection by Deflagration Venting.*

19.8.1.15.2 All enclosed passageways that connect with one or more processing areas shall be provided with means of egress in accordance with NFPA *101, Life Safety Code.*

19.8.1.16 Grounding and Lightning Protection.

19.8.1.16.1* All process equipment and all building steel shall be bonded and grounded in accordance with *NFPA 70, National Electrical Code.*

19.8.1.16.2 All buildings shall be provided with a lightning protection system in accordance with NFPA 780, *Standard for the Installation of Lightning Protection Systems.*

19.8.1.16.3 Lightning protection systems shall not be required for office buildings and buildings that are used for storage and handling of closed containers.

19.8.1.17 Heating and Cooling of Production Buildings.

19.8.1.17.1 Buildings shall be permitted to be heated by indirect hot-air heating systems or by bare-pipe heating systems using steam or hot water as the heat transfer medium, or by listed electric heaters.

19.8.1.17.2 Indirect hot air shall be permitted if the heating unit is located in an adjacent room or area that is free of combustible dust.

19.8.1.17.3 Fans or blowers used to convey heated or cooled air shall be located in an area that is free of combustible dust.

19.8.1.17.4 The air supply shall be taken from outside or from a location that is free of combustible dust.

19.8.1.17.5 Makeup 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.

19.8.1.17.6 The requirements of 19.8.1.17.1 through 19.8.1.17.5 shall not apply to areas where combustible metal is melted.

19.8.2 Fire Protection.

19.8.2.1 Fire protection shall be in accordance with Chapter 6.

19.8.3 Electrical Classification.

19.8.3.1 Electrical classification shall be in accordance with Section 8.8.

19.8.4 Hazard Analysis. Hazard analysis shall be in accordance with Section 5.2.

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 6.4 and 6.5.

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 6.3.3.5 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 6.

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, *Flammable and Combustible Liquids Code.*

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, *Fire Code.*

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, National Electrical Code.*

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 8.

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 9.

19.11 Fire and Explosion Prevention.

19.11.1 The requirements of Chapter 6 shall apply.

19.11.2 Housekeeping.

19.11.2.1 The requirements of Chapter 7 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.1.1.3 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).]*

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

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	—

*Maximum adiabatic flame temperature calculations from Cashdollar and Zlochower, *J. Loss Prevention*, v 20, 2007.

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/m^3)	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
Zinc (from collector)	10	176	7.3	—	—	125	BZ 2		Eckhoff

(continues)

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/m^3)	VDI Combustibility Class[2]	LOC[1] (v%)	Data Source
Zinc (from Zn coating)	19	85	6	800	—	—	BZ 2		Eckhoff
Zinc (from Zn coating)	21	93	6.8	790	—	250	—		Eckhoff
Zirconium	<44	—	5.2	20	5	45	—	Ignites in N_2 & CO_2	BuMines RI 6516
Zirconium (Zircalloy-2)	50	—	3.0	420	30	—	—	—	BuMines RI 6516

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

2. VDI Guidelines 2263, Part 1, *Test Methods for the Determinations of Safety Characteristics Dusts*, Classes are as follows:
(1) BZ1 No self-sustained combustion
(2) BZ2 Local combustion of short duration
(3) BZ3 Local sustained combustion, but no propagation
(4) BZ4 Propagating smoldering combustion
(5) BZ5 Propagating open flame
(6) BZ6 Explosive combustion

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

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

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.

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, *Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities*, NFPA 120, *Standard for Fire Prevention and Control in Coal Mines*, NFPA 495, *Explosive Materials Code*, NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, NFPA 655, *Standard for Prevention of Sulfur Fires and Explosions*, and NFPA 664, *Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities.*

A.1.1.6.2 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, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 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.*

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 4. The quantities listed in Table 1.1.11 are for the entire occupancy, not for individual fire control areas.

A.1.4.2 The requirements identified in Chapter 6 and Chapter 19 are applicable to new and existing facilities.

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.3.3.4.1 Heavy Casting. Castings less than 11.3 kg (25 lb) are considered light castings.

A.3.3.5 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.

A.3.3.6.1 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.

Dusts traditionally have been defined as a material 420 microns or smaller (capable of passing through a U.S. No. 40 standard sieve). For consistency with other standards, 500 microns (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 microns generally have a surface to volume ratio that is too small to pose a deflagration hazard. Flat platelet-shaped particles, flakes, or fibers with lengths that are large compared to their diameter usually do not pass through a 500 micron sieve yet could still pose a deflagration hazard. Many particulates accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often, agglomerates behave as if they were larger particles, yet when they are dispersed they present a significant hazard. Consequently, it can be inferred that any particle that has a minimum dimension of less than 500 microns could behave as a combustible dust if suspended in air.

The determination of whether a sample of material is a combustible, explosible, dust should be based on a screening test methodology such as that provided in the draft ASTME 1226, *Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts*. 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 Liter sphere when tested by the ASTM E1226 screening test or ASTM E 1515 test. This is due to the high energy ignition source over-driving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale ($\geq 1\ m^3$) enclosure, which is less susceptible to over-driving and thus will provide more realistic results.

This possibility for false positives has been known for quite some time and is attributed to over-driven conditions that exist in the 20 liter chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from 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 …" ASTM E1226 further states, "Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and $P_{\max}$ parameters are known in the 1 m^3 chamber."

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

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

A dust deflagration has the following four requirements:

(1) Combustible dust
(2) Dust dispersion in air or other oxidant
(3) Sufficient concentration at or exceeding the minimum explosible concentration (MEC)
(4) Sufficiently powerful ignition source such as an electrostatic discharge, an electric current arc, a glowing ember, a hot surface, welding slag, frictional heat, or a flame

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

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

(1) MEC
(2) Minimum ignition energy (MIE)
(3) Particle size distribution
(4) Moisture content as received and as tested
(5) Maximum explosion pressure at optimum concentration
(6) Maximum rate of pressure rise at optimum concentration
(7) K_{St} (normalized rate of pressure rise) as defined in ASTM E1226-2010, *Standard Test Method for Explosibility of Dust Clouds*
(8) Layer ignition temperature
(9) Dust cloud ignition temperature
(10) Limiting oxidant concentration (LOC) to prevent ignition
(11) Electrical volume resistivity
(12) Charge relaxation time
(13) Chargeability

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

A.3.3.6.3 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.3.3.7 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

A.3.3.16 Fire-Resistive. The requirements are described in NFPA 220, *Standard on Types of Building Construction.*

A.3.3.22 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.

A.3.3.23.2 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, *Flammable and Combustible Liquids Code*, and NFPA 77, *Recommended Practice on Static Electricity*, are applicable to addressing the problems of combustible liquids and vapors.

A.3.3.23.3 Spark-Resistant Material. See AMCA Standard 99-1401-86, "Classifications for Spark Resistant Construction," for additional information.

A.3.3.25 Mesh Size. Table A.3.3.25 provides mesh sizes.

Table A.3.3.25 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.3.3.26 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.3.3.26.2 Combustible Metal. See A.1.1.3 for further information on determining the characteristics of metals.

A.3.3.26.4 Metal-Containing Mixture. Intentional mixtures range from formulations by blending or compounding of metals with non-metals (organics, salts, inorganics) for use as intermediates, final products, 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.3.3.27 Minimum Explosible Concentration (MEC). Minimum explosible concentration is defined by the test procedure in ASTM E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts.*

The MEC is sometimes incorrectly referred to as the lower flammable limit (LFL) or lower explosive limit (LEL). Dusts have no upper explosive concentration.

A.3.3.29 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.3.3.32.1 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.3.3.32.3 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.3.3.32.4 Combustible Metal Powder. See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, or NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, for information on explosibility parameters of combustible dusts.

A.3.3.33 Powder Production Plant. Facilities or buildings in which powder or combustible dust is produced incidentally to operations are not considered powder production plants.

A.3.3.35 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.3.3.37.1 Magnesium Ribbon. It should be considered a powder for storage.

A.3.3.40 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.3.3.45 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.

A.4.1 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.4.1.5 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.4.2 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.4.2.1 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.4.2.2 See Figure A.4.2.2 for typical basic material characterization.

A.4.3.1 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.

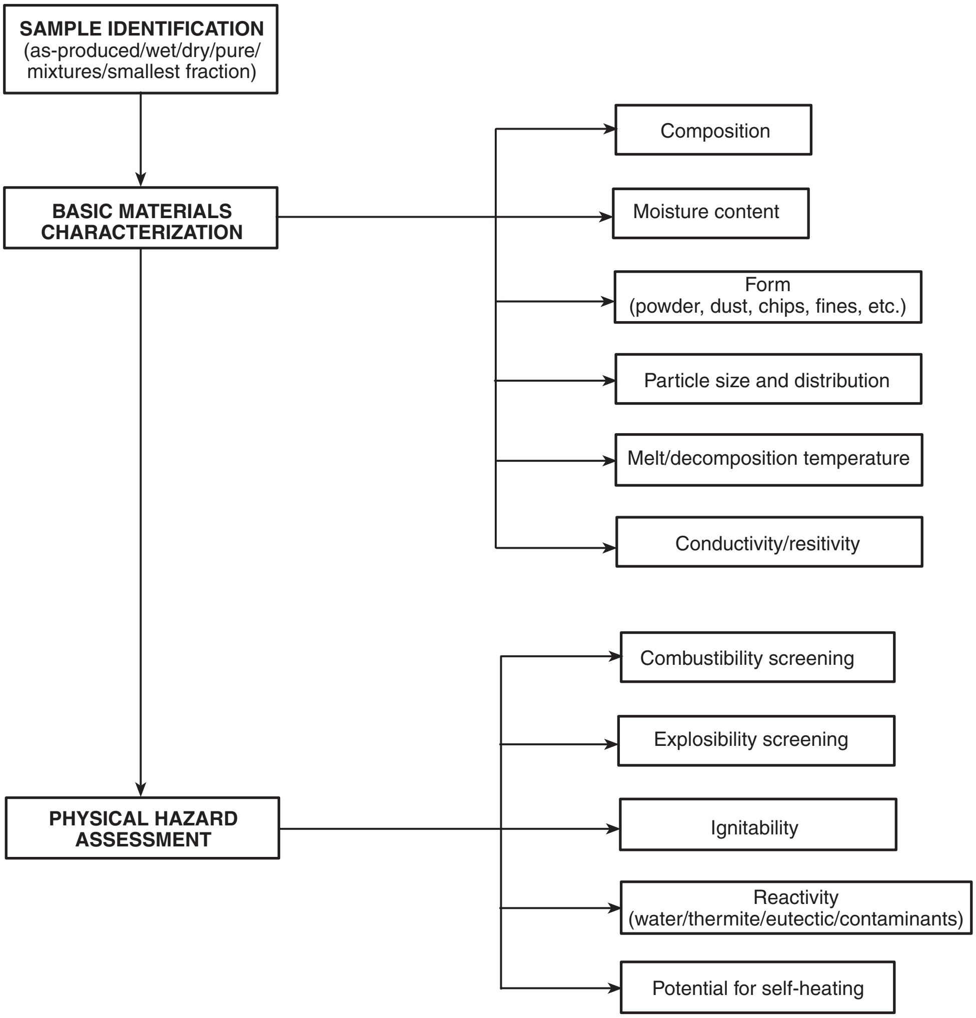


FIGURE A.4.2.2 Examples of Basic Materials Characterization.

(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.4.3.4 Results of the preliminary screening test can have one of the following four results:

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

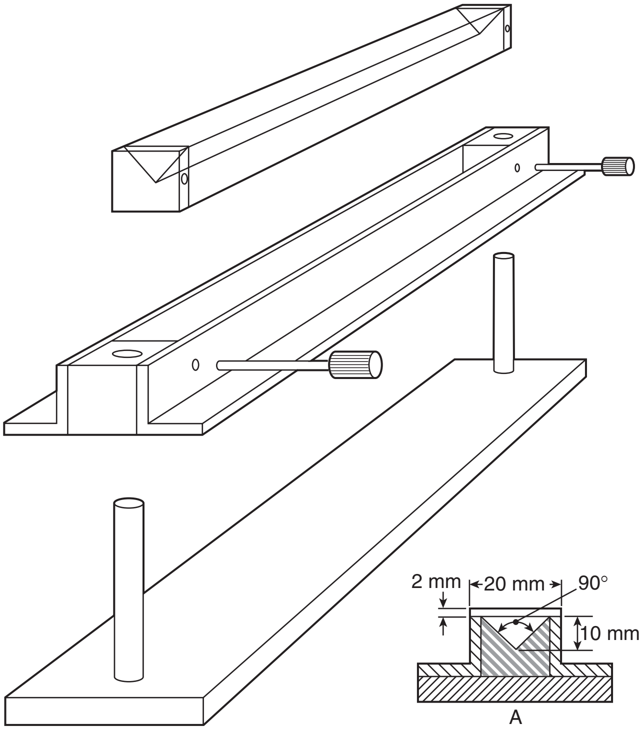
If the results of the screening test show no reaction or glowing in the specific form, that material can be considered noncombustible and does not fall under the requirements of this document.

If the results of the screening test show glowing but no propagation along the powder train, the material in the specific form should be considered a limited-combustible material. Hazard analysis should be conducted to determine the extent to which the requirements of this document are applicable. It is recommended for general safety that the full requirements be met.

If the results of the screening test show propagation of the powder train, the material in the specific form should be considered a limited-combustible material and full compliance with the requirements of this document be met.

If the results of the screening test show propagation of the powder train sufficiently fast that the form is classified as a Division 4.1 material, hazard analysis should focus on additional protocols and compliance with other NFPA standards.

A.4.3.5 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.4.3.5.



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

FIGURE A.4.3.5 Fixture for Preparation of Sample for Burning Rate Test.

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.

A.4.3.5.1 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.4.4.1 Table A.4.4.1 gives a small sample of published ignition and explosion data on various sizes of aluminum powders.

A.4.4.2 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 ASTM E1515 test. This is due to the high energy ignition source over-driving the test. When the lowest ignition energy allowed by either method still results in a positive result, the owner/operator can elect to determine whether the sample is a combustible dust with screening tests performed in a larger scale (≥1 m^3) enclosure, which is less susceptible to over-driving and thus will provide more realistic results.

This possibility for false positives has been known for quite some time and is attributed to over-driven conditions that exist in the 20 L chamber due to the use of strong pyrotechnic igniters. For that reason, the reference method for explosibility testing is based on 1 m^3 chamber, and the 20 L chamber test method is calibrated to produce results comparable to those from 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.” ASTM E1226 further states, “Because a number of factors (concentration, uniformity of dispersion, turbulence of ignition, sample age, etc.) can affect the test results, the test vessel to be used for routine work must be standardized using dust samples whose K_{St} and $P_{\max}$ parameters are known in the 1 m^3 chamber.”

NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, also recognizes this problem and addresses it: “ 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.”

A.4.4.3 Explosive properties are dramatically affected by changes in physical properties, chemical composition, particle

Table A.4.4.1 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.

size distribution, amount of fines, and mean particle size. These changes can be due to variations in process operating parameters, substitutions in shop and feedstock supplies, changes to shop supply providers, and process or transport equipment changes including normal equipment wear. Test sample selection should include an assessment of the extent of these nominal process, equipment and material variations in order to select a sample representative of the finest particulates and compositions that are likely to enhance explosibility. If explosibility and particle size variations cannot be assessed without testing, multiple samples should be collected and submitted for testing.

If normal composition of the material includes a high moisture content but subsequent drying or exposure to elevated temperature of the material occurs, it is highly advisable that parallel testing of the material at low moisture content be performed. Some materials are subject to change, such as oxidization or other chemical reaction that could affect the test results. Precautions, such as inerting or vacuum packing, should be taken to preserve the test sample integrity during packaging, shipping and testing.

A.4.4.4 Testing for the minimum ignition energy (MIE) of a combustible particulate is carried out in accordance with the following recognized international standards: ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air*, and BS 5958-1, *Code of Practice for Control of Undesirable Static Electricity: General Considerations.*

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 spark energy at which ignition ceases is the MIE.

Explosibility Test. The explosibility test serves to identify the maximum unvented deflagration pressure a material is capable of producing under optimum conditions of dust cloud concentration, as well as the maximum speed of the explosion.

This explosion severity test is carried out in accordance with the ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or EN 14034-1:2004+A1:2011 *Determination of Explosion Characteristics of Dust Clouds – Part 1: Determination of the Maximum Explosion Pressure P max of Dust Clouds*; and EN 14034-2:2006+A1:2011 *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. 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. c_w is used in this document 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.4.4.4. The higher a powder *St* class number, the more energetic the explosion and the greater the speed of the explosion.

Table A.4.4.4 Explosive Energy Classification

***St* Class**	**K_{St} (bar-m/sec^{-1})**
St 1	>0–200
St 2	201–300
St 3	>300

Limiting Oxidant Concentration (LOC) Test. The purpose of the test is to determine the the oxygen concentration below which the ignition of the dispersed dust is not possible.

The test is conducted in accordance with the draft ASTM standard, or a modified EN 14034-4:2004+A1:2011 *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 and draft ASTM 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 a modified EN 14034-3:2006 A1:2011 *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.4.5.1 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.4.5.2 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.4.6 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.

A.5.1 It is essential to have thorough written documentation, as the slightest changes to procedures, processes, and/or equipment, including from suppliers, can have a dramatic impact on the overall hazard analysis. Changes include something as seemingly benign as process materials, replacements-in-kind from a different manufacturer, the same manufacturer using new methods to produce the product, or changes in formulation. These changes from a supplier's end can impact the characteristics of the processes and/or materials.

A.5.2.1 One method by which this requirement can be satisfied is with a hazard analysis conducted in accordance with the methods outlined by the American Institute of Chemical Engineers' Center for Chemical Process Safety in *Guidelines for Hazard Evaluation Procedures.*

To determine if a dust deflagration hazard exists, consider the following:

(1) Is the dust explosible? Determine using ASTM E1226, *Standard Test Method for Explosibility of Dust Clouds*, or its equivalent.
(2) Determine where in the process a dust cloud sufficient to support a deflagration could occur. Use loss records and knowledge of process conditions to make this assessment.
(3) Identify likely ignition sources. Recognize that ignition sources are complex and not always predictable. It is best to assume ignition is possible in all cases.
(4) Assess the likelihood of an event. For example, a material with a low MIE has a greater likelihood of ignition, all else being equal. Determine MIE, if appropriate, using ASTM E2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air.*
(5) In terms of a worst-case scenario, consider the predictable consequences. Start with predictable primary events and then secondary events.
(6) If the consequences are intolerable to either the owner/operator or the AHJ, ask the following:
  (a) Can the risk be eliminated?
  (b) Can controls be applied to minimize the likelihood?
  (c) Can the risk be tolerated utilizing mitigation techniques to reduce or control the consequences?

A.5.3 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 U.S. Chemical Safety Board Case Study Report on Hoeganaes Corp. fatal flash fires.)*

A.5.3.1.2 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.5.3.2.3 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.

A.5.3.3.1 NFPA 2113 describes requirements and criteria for wearing garments made and tested in accord with NFPA 2112, *Standard on Flame-Resistant Garments for Protection of Industrial Personnel Against Flash Fire.*

A.5.3.3.2 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 firefighting applications, NFPA 1971, *Standard on Protective Ensemble for Structural Fire Fighting and Proximity Fire Fighting* and for arc flash protection; 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 are no test data to substantiate their performance for metal dust fires.

A.5.3.3.6 Heat-resistant fabrics include, but are not limited to, Kevlar, Nomex, and heavy leather.

A.5.3.3.7 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.5.3.4.4 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.5.3.4.5.1 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, *Standard on Fire Department Occupational Safety and Health Program.)*

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.

A.5.5.3.1 A relatively small initial dust deflagration can disturb and suspend in air dust that has been allowed to accumulate on the flat surfaces of a building or equipment. Such a dust cloud provides fuel for the secondary deflagration, which can cause damage. Reducing significant additional dust accumulations is therefore a major factor in reducing the hazard in areas where a dust hazard can exist.

A.5.5.3.4 A building could be considered as a single dust flash-fire hazard area, or as a collection of smaller, separated dust flash-fire 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 dust flash-fire hazard areas are sufficiently distant to assert separation and the owner/operator chooses to consider each hazard area separately, then the hazard analysis should consider each separated area and the considerations for mitigation 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 dust flash-fire hazard areas. If the separation option is chosen, a building floor plan, showing the boundaries considered, should be maintained to support housekeeping plans.

A.6.2.3 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.6.3.1.1 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.6.3.1.2 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.6.3.1.6 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, *Standard for the Installation of Sprinkler Systems.*

A.6.3.2.1 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.6.3.2.6 See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A.6.3.3 Table A.6.3.3 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.6.3.3.1 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.6.3.3.5(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

Table A.6.3.3 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
Coke (carbon microspheroids)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Met-L-X	Yes*	No	Yes*	Yes	Yes*	Yes*	Yes*	Yes*	Yes*
Lith-X	Yes*	Yes*	No	No	No	No	No	No	No
Copper powder	Yes*	Yes*	Yes	No	No	No	No	No	No
Dry flux	Yes	Yes	Yes*	No	Yes*	No	No	No	No
Dry sand	Yes	Yes	Yes*	Yes	Yes*	Yes*	Yes*	Yes*	Yes*
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*	No	Yes*	Yes*	Yes*	Yes*	Yes*
Water	No	No	No	Yes	No	No	No	No	No
Foam	No	No	No†	Yes	No	No	No	No	No
Argon	Yes*	Yes	Yes*	Yes	Yes*	Yes*	Yes*	Yes*	Yes*
CO_2	No	No	No	No	No	No	No	No	No
Nitrogen	Yes*	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.

*Preferred extinguishing agent.

†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.

nitrogen–argon blends have been shown to be an effective extinguishing agent for some combustible metals.

A.6.3.3.9 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.6.3.3.9.2.1 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.6.3.3.9.2.2 Re-ignition can occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

A.6.3.3.10.1 The use of fine, dry sand, preferably less than 20 mesh, or other approved powder is an effective method of isolating incipient fires in combustible-metal dust. An ample supply of such material should be kept in covered bins or receptacles located in the operating areas where it can be reached at all times. A long-handled shovel of spark-resistant metal should be provided at each such receptacle to afford a ready means of laying the material around the perimeter of the fire.

Nearly all vaporizing liquid–fire-extinguishing agents react violently with burning combustible metal, usually serving to greatly intensify the fire and sometimes resulting in explosion.

Water hose streams should not be used. The impact of the water stream can lift enough dust into the air to produce a strong dust explosion. In addition, water reacting with aluminum can give off highly flammable hydrogen gas.

A.6.3.3.10.3 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.6.3.4.1 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.6.3.4.8.1 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.6.3.4.9.1 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.6.3.4.9.2 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.6.3.5.2.2 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.

A.6.4 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.6.4.1(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.6.4.1(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.6.5.2 Employee health and safety in operations depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

A.6.5.4 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.6.5.7 Fire blankets have been found to be effective for extinguishing clothing fires. They should be distributed in plant areas where water is excluded.

A.7.2 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, *Standard on Selection, Care, Use, and Maintenance of Flame-Resistant Garments for Protection of Industrial Personnel Against Short-Duration Thermal Exposures from Fire*
(4) Cleaning sequence
(5) Cleaning methods to be used
(6) Equipment, including lifts, vacuum systems, attachments, etc.

A.7.3.1 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.7.3.2 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.

A.7.4 Unscheduled housekeeping should be performed in accordance with Table A.7.4(a) to limit the time that a local spill or short-term accumulation of dust is allowed to remain before cleaning the local area to less than the threshold dust mass/accumulation.

Table A.7.4(b) shows approximate equivalent depths for the accumulation values in Table A.7.4(a) when the threshold dust mass/accumulation is 1 kg/m^2. The owner/operator can use an approximate depth to facilitate communication of housekeeping needs.

A.7.5 Permanently installed vacuum cleaning systems provide the maximum safety because the dust-collecting device and the exhaust blower can be located in a safe location outside the dust-producing area.

A.7.5.2 See NFPA 77, *Recommended Practice on Static Electricity.*

A.7.5.3 Utility vacuums or residential, automotive, hobby, or household portable vacuums should not be used.

A.7.5.4 It is recommended that no more than 2.2 kg (5 lb) of dust should be collected at any one time before being emptied. A vacuum cleaner should be checked to be sure that it is empty before each use. A vacuum cleaner should be emptied at the end of each use.

Improper use of vacuum cleaners for combustible metal powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A.7.5.5 For example, iron oxide dusts are known to be incompatible with titanium, aluminum, magnesium, and other

Table A.7.4(a) Examples of Unscheduled Housekeeping

Accumulation on the Worst Single Square Meter of Surface	Longest Time to Complete Unscheduled Local Cleaning of Floor-Accessible Surfaces	Longest Time to Complete Unscheduled Local Cleaning of Remote Surfaces
>1 to 2 times threshold dust mass/accumulation	8 hours	24 hours
>2 to 4 times threshold dust mass/accumulation	4 hours	12 hours
>4 times threshold dust mass/accumulation	1 hour	3 hours

Table A.7.4(b) Examples of Unscheduled Housekeeping

Accumulation on the Worst Single Square Meter of Surface		Average Depth at 75 lb/ft^3		Average Depth at 30 lb/ft^3	
kg/m^2	lb/ft^2	mm	in.	mm	in.
>1 to 2	>0.2–0.4	0.8–1.7	>1⁄32–1⁄16	2.1–4.2	>5⁄64–5⁄32
>2 to 4	0.4–1.6	1.7–3.3	>1⁄16–1⁄8	4.2–8.3	>5⁄32–5⁄16
>4	>1.6	>3.3	>1⁄8	>8.3	>5⁄16

metal dusts due to the potential for an exothermic thermite reaction *(see A.3.3.45 for additional information).* The dust-separating unit should be cleaned unless it has been determined that the materials exhibit no incompatibility.

A.7.8.1 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.7.8.3 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.8.1 It is not always possible or practical for existing facilities to be in compliance with new provisions of a standard on the effective date of that standard. Therefore, retroactivity in this section means that a plan to achieve compliance within a reasonable time frame should be established.

A.8.2 Attention is called to the hazardous conditions that could exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around metal powder plants.

A.8.3.1 Separation distances between a designated smoking area and areas where combustible metals are present are defined through a hazards analysis.

A.8.4.1 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.8.4.2 Under certain circumstances, such as impacts with rusted iron or steel, aluminum cannot safely be considered to be nonsparking, since a minor thermite reaction can be initiated. For details, refer to Eisner, "Aluminum and the Gas Ignition Risk," and Gibson et al., "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction."

Bonded and grounding of hand tools most often occurs through the person handling the tools. The use of insulating gloves or shoes could interrupt this grounding and bonding path.

A.8.5 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.8.5.1 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.

A.8.5.2 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 antistatic 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.

A.8.5.3 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 niobium powders being processed.

A.8.5.7 NFPA 77, *Recommended Practice on Static Electricity*, provides guidance on how to ground personnel. The most common methods of personnel grounding are through conductive flooring and footwear or through dedicated personnel-grounding devices such as wrist straps. Grounding devices should provide a resistance to ground between 10^6 and 10^8 ohms. The lower resistance limit (10^6 ohms) is specified to protect personnel from electrocution due to inadvertent contact with energized electrical equipment, while the upper resistance limit (10^8 ohms) is specified to ensure adequate charge dissipation. Grounding devices should be tested regularly, and cleaning should be performed to ensure that accumulations of noncombustible residues do not interfere with continuity.

A.8.5.7.2(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.

A.8.5.7.2(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.8.6.2.2 Information on spark-resistant fans and blowers can be found in AMCA Standard No. 99-0401-10, "Classifications for Spark Resistant Construction."

A.8.6.2.4 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.8.6.3 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.8.8.1 See NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*; and NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, for information on electrical area classification. Housekeeping can be used to reduce or eliminate the electrical area classification for a location where combustible metal dust is present. The upgrading of electrical equipment to meet Article 500 of *NFPA 70* can be costly and users might better focus on preventing fugitive dust escaping from equipment and accumulations to minimize the extent of the hazardous (classified) areas.

A.8.8.3 Finding combustible metal dust or powder within electrical equipment and components should warrant more frequent inspection and cleaning.

A.8.9.2 Diesel-powered, front-end loaders suitable for use in hazardous locations have not been commercially available. The following provisions can be used to reduce the fire hazard from diesel-powered, front-end loaders used in Class II hazardous areas, as defined in Article 500 of *NFPA 70, National Electrical Code*:

(1) Only essential electrical equipment should be used, and wiring should be in a metal conduit. Air-operated starting is preferred, but batteries are permitted to be used if they are mounted in enclosures rated for Type EX hazardous areas.
(2) Where practical, a water-cooled manifold and muffler should be used.
(3) Loaders that are certified to meet the Mine Safety and Health Administration (MSHA) criteria (formerly Schedule 31) found in 30 CFR 36, "Approved Requirements for Permissible Mobile Diesel-Powered Transportation Equipment," are also acceptable in lieu of A.8.9.2(1) and A.8.9.2(2).
(4) The engine and hydraulic oil compartments should be protected with fixed, automatic dry-chemical extinguishing systems.
(5) Loaders should have a high degree of maintenance and cleaning. Frequent cleaning (daily in some cases) of the engine compartment with compressed air could be necessary. Periodic steam cleaning also should be done.
(6) Loaders should never be parked or left unattended in the dust explosion hazard or dust fire hazard area.

A.8.10.1 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.9.2.1.3 For more information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.2.1.4 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.9.2.1.5 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 *Industrial Ventilation — A Manual of Recommended Practice for Design*, published by the American Conference of Governmental Industrial Hygienists (ACGIH).

A.9.2.1.6 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 the 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 collector at the end of the system unless the dust is collected in liquid, such as in a spray tower. In addition, the powder in the conveying line from the atomizer to the collector will, of necessity, approach the MEC.

A.9.2.1.7 For information on spacing and sizing of ductwork deflagration vents, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.2.1.7.1.3 Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.2.1.8 Typically, for most metals the pressures the ductwork is designed to ranges from 690 kPa (100 psi) to 872 kPa (125 psi). The user should be aware that certain metals could transition to detonations in the ductwork that would require higher design pressures.

A.9.2.2.1 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.9.2.2.3 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 the U.S. Bureau of Mines publication, RI 3722, "Inflammability and Explosibility of Metal Powders."

A.9.2.2.4 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.9.2.2.6 Condensing moisture can cause material to stick to ducts and can exothermically react with most combustible metals generating hydrogen.

A.9.2.2.7 Condensing moisture might cause material to stick to ducts and can exothermically react with most combustible metals generating hydrogen.

A.9.2.2.8 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 *Industrial Ventilation — A Manual of Recommended Practice for Design*, published by the American Conference of Governmental Industrial Hygienists (ACGIH).

A.9.2.3.4 Ultimately, all fans or blowers in dust collection systems accumulate sufficient powder to become a potential explosion hazard.

A.9.3.1 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, *Standard on Explosion Protection by Deflagration Venting*. Care should be exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.9.3.1.2 See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, for the method to calculate the length of a fireball issuing from a vented collector.

A.9.3.1.2.2 Historical data have shown that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.3.1.5 For information on precautions for static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.3.1.7 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, *Standard on Explosion Protection by Deflagration Venting*. Dust collectors, when provided by a manufacturer for other applications, seldom have properly sized venting to handle a combustible metal dust explosion.

A.9.3.2.2 The blank is provided for segregation and must be removed before restoring the equipment to operation.

A.9.3.4 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.9.4 There are two recognized methods of collecting combustible metal dust in industrial operations. Wet-type dust collectors should be located indoors near the point of dust generation; dry-type dust collectors should be located outdoors as close as possible to the point of dust generation. Dry-type dust collectors are not recommended for niobium or tantalum dust. There are some specialized applications where indoor dry-type dust collectors can be tolerable for the collection of metal dusts, when wet-type dust collectors or dry-type outdoor dust collectors are not feasible.

A.9.4.1 MECs for combustible metal dusts in air are published in U.S. Bureau of Mines, RI 6516, "Explosibility of Metal Powders." Although the metal dust–air suspension normally can be held below the MEC in the conveying system, the suspension can pass through the flammable range in the collector at the end of the system.

A.9.4.3 Often, individual wet-type dust collectors can be provided for each dust-producing machine so that ductwork connecting the hood or enclosure of the machine to the collector is as short as possible.

A.9.4.6 Condensing moisture might cause material to stick to ducts and can exothermically react with most combustible metals generating hydrogen.

A.9.4.7 See A.9.4.6.

A.9.4.10.2 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 *Industrial Ventilation — A Manual of Recommended Practice for Design*, published by the American Conference of Governmental Industrial Hygienists (ACGIH).

A.9.4.10.3 U.S. Bureau of Mines, RI 6516, "Explosibility of Metal Powders," reports the results of tests conducted on 89 samples of metal powders of various grades and sizes. Minimum ignition energies (MIEs) for dust clouds ranged up to 15 mJ, whereas MIEs for dust layers ranged upward from 15 mJ. Ignition temperatures ranged upward from 320°C (608°F). MECs ranged upward from 40 g/m^3 (0.040 oz/ft^3). Maximum explosion pressures can exceed a gauge pressure of 620 kPa (90 psi).

A.9.4.10.4 Short, straight ducts reduce the explosion hazard and minimize the likelihood of accumulations of dry dust. Also, accumulations of tallow, wax, or oil with metallic fines and lint can be seen readily and more easily removed.

A.9.4.10.5.7 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.4.11 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.4.11.3 Some collector bags or other types of media or screens have fine, noninsulated wire enmeshed into or woven with the cloth or otherwise fastened to it. 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.9.4.12.1 The reaction of water and most combustible metals produces hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures. Exhaust vents should be located in areas free of potential ignition sources because of the possible production of hydrogen, which is flammable.

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 NFPA 55, *Compressed Gases and Cryogenic Fluids Code*, Table 10.3.2.1, Location of Gaseous Hydrogen Systems, 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.9.4.12.4.3(a), Figure A.9.4.12.4.3(b), and Figure A.9.4.12.4.3(c).]*

A.9.4.12.3 The humid air of the wet-type dust collector wets the fine particles that pass through the collector so that the particles agglomerate and tend to build up a highly combustible cake- or spongelike deposit (sludge) on the inner wall of the exhaust duct.

A.9.4.12.4.3 Figure A.9.4.12.4.3(a), Figure A.9.4.12.4.3(b), and Figure A.9.4.12.4.3(c) show examples of liquid precipitation collectors.

A.9.4.12.5 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.9.4.12.6.1 Water level in the operation of wet-type dust collectors is very important to the overall efficiency of the equipment. Therefore, water level control logic that shuts the machine down in an under-fill or over-fill situation is necessary. In

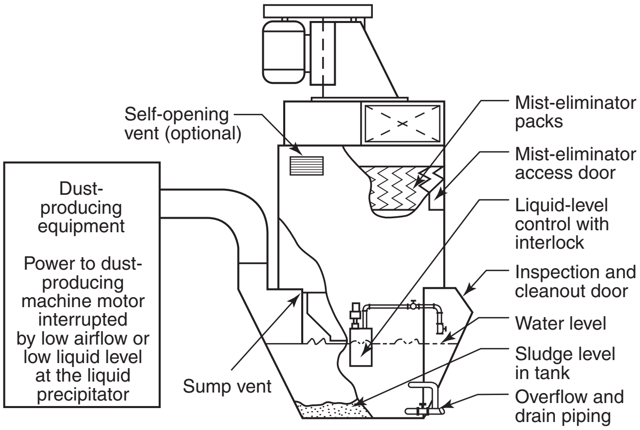


FIGURE A.9.4.12.4.3(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

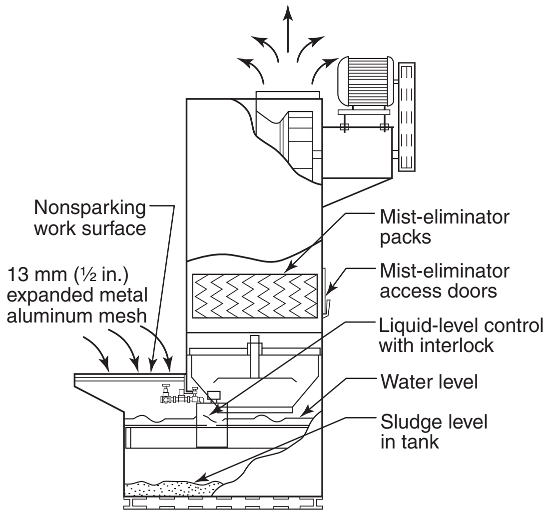


FIGURE A.9.4.12.4.3(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

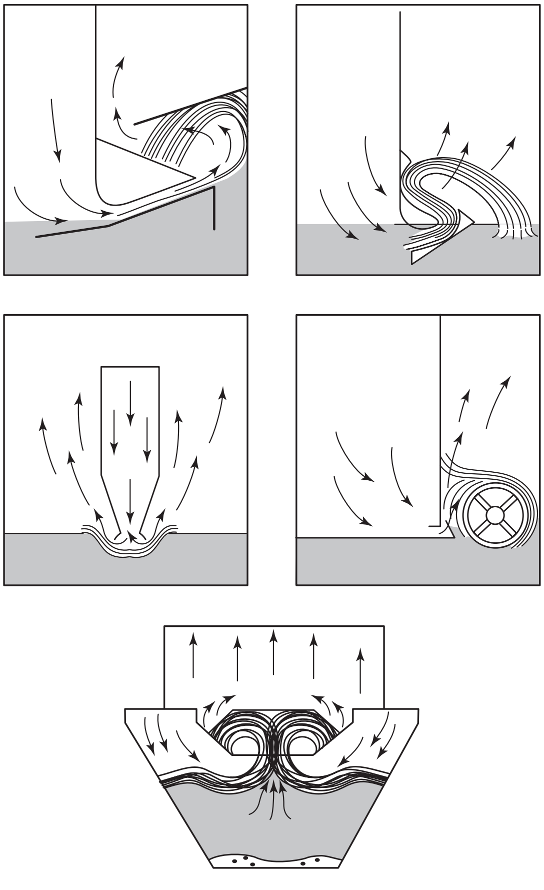


FIGURE A.9.4.12.4.3(c) Five Methods of Precipitating Dust in Precipitators.

both situations, power to the dust collector should drop out and both visual and audio alarms should energize to warn operators of the condition.

A.9.4.12.7 Hazardous conditions could exist both inside and outside a plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed. A commonly recognized practice requires operators of cutting or welding torches to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around combustible metal powder plants.

A.9.4.12.7.2 Containers preferably should not hold more than 23 kg (50 lb) each.

A.9.4.12.7.5 For proper disposition of sludge, waste material should be characterized in accordance with 40 CFR Part 261 Subpart (B).

A.9.4.13 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 the atmosphere, away from other operations. It should be recognized that there will be some instances in which a centrifugal-type 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 collector should be recognized, and protection against the hazards should be provided. 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 is 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 bag-house 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, *Standard on Explosion Protection by Deflagration Venting*. Care should be exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures. Dry-type dust collectors are not recommended for niobium or tantalum dust.

A.9.4.13.1 Electrostatic collectors inherently introduce a potential ignition source based on their method of operation.

A.9.4.13.2 Figure A.9.4.13.2 is an example of a media-type dust collector. The figure shows the major system components.

A.9.4.13.3 See Figure A.9.4.13.3.

A.9.4.13.3.4 This is not intended establish the physical retention capacity, but rather to establish procedural steps to be implemented to ensure that the retained material is less than the 2.2 kg (5 lb) allowance.

A.9.4.13.13.1(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, *Standard on Explosion Protection by Deflagration Venting*. 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.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

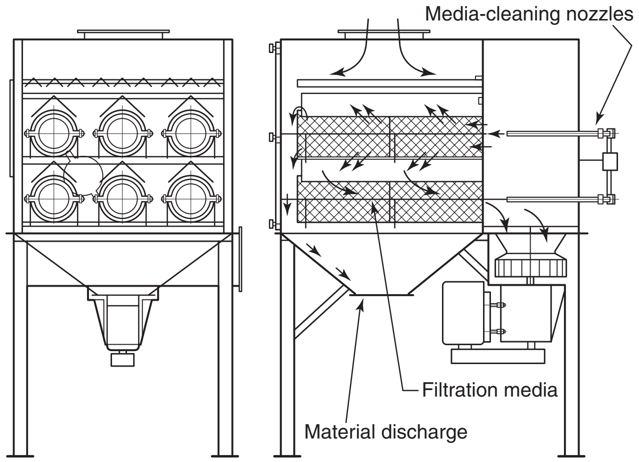


FIGURE A.9.4.13.2 Example of a Fixed Media-Type Dust Collector.

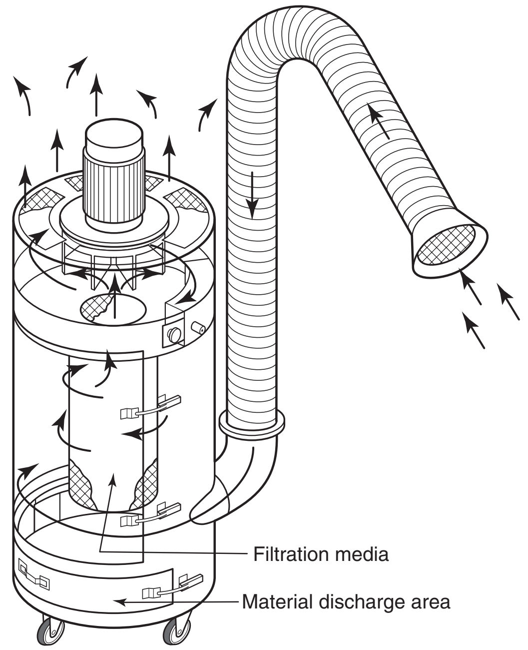


FIGURE A.9.4.13.3 Example of a Portable Media-Type Dust Collector.

A.9.4.13.13.1(1)(b) Most combustible metals will react with water. The oxygen in water can oxidize the metal and generate hydrogen. In most cases, deflagration vent ducts designed for a 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. Historical data show that in the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.4.13.13.1(2)(b) 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, with many combustible metals it is not advisable 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.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.4.13.13.1(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.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the protection is suitable against an explosion hazard.

A.9.4.13.13.1(5) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling.

A.9.4.13.13.1(6) For information on dust retention and flame-arresting devices, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, Section 9.7. 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.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.4.13.13.3.1 The purpose of this requirement is to protect dust collectors that have combustible metals present in the collector. Many dry-type dust collectors are utilized for collection of grinding and similar operations in which the collected material is not combustible, and in those cases, isolation would not be required.

Historical data show that the application of relationships in NFPA 68 and NFPA 69 based on K_{St} values for explosion suppression, isolation, and venting might not be suitable for certain combustible metal dusts. Caution must therefore be used when applying relationships provided in NFPA 68 and NFPA 69 to metal dusts, and it is important to base the protection's performance on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.4.13.14.1 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 (collector, duct, etc.). For this reason it is important to base the protection's ability on the actual dust and process under review. The manufacturer of the protection equipment should provide experimental justification that the explosion protection is suitable for the hazard.

A.9.4.13.14.4 Operations prone to spark generation include grinding, cutting, sanding, and abrasive blasting.

A.9.4.13.14.7 The following is an example of a procedure for replacing filter media:

Required equipment:

(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

Procedure:

Notify system operators that the affected dust collection systems will be shut down and locked out in accordance with the company Lock-Out/Tag-Out procedure.

(1) Shut down all processes providing powder to the collector (atomization, classification, etc.)
(2) Isolate the collector by means of valves or blank-off plates in ductwork.
(3) Disable and lock out pulsing system associated with the collector.
(4) If a forklift/cage is required for access to the collector, the forklift and cage shall be bonded to the collector frame by bonding cables and clamps.
(5) 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.
(6) Open the collector access door/port using nonsparking tools.
(7) Remove the cartridges/bags, taking care to minimize the generation of suspended dust.
(8) Cartridges/bags that have been removed shall be handled in accordance with established cleaning and disposal procedures.
(9) Install the new cartridges/bags.
(10) Perform and document a continuity check.
(11) Reinstall the access door/port.
(12) 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.
(13) Open the valves leading to/from the collector, or remove any blank-off plates previously installed.

(14) Purge the collector, if required, and contact QC for purge sign off.
(15) Remove all locks/tags previously installed and reenergize the pulse system.
(16) 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.9.4.13.15.4.2 Indoor dry-type dust collectors for combustible metal dust should be used only where it is not feasible to use an indoor wet-type collector or outdoor dry-type dust collector. In most cases, an indoor dry-type dust collector will create a greater hazard than other options. For instance, a fire in an indoor dry-type dust collector can more readily spread to the building. A combustible metal fire in an indoor dry-type dust collector 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 dust collectors are allowed only for combustible metals that meet certain thresholds for ignitability and explosion severity, and the collector requires a greater level of protection.

A.9.4.13.15.6 For example, for steel, a warning label 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.9.4.13.15.7.6 A break in a filter can allow dust to pass through the rotating fan, which would create a hazard.

A.9.4.13.15.7.8 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.9.4.13.15.7.9(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 systems 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.

A.9.4.13.15.7.10 For example, for steel, a warning label 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.9.4.13.15.7.11 It is recommended that indoor dry-type dust collectors for all combustible metals meet these requirements.

A.9.4.13.15.7.11(2) Most combustible metals cannot be effectively extinguished with water because of the potential for steam explosions and reaction of water with the metal generating hydrogen. Table A.6.3.3 should be consulted to determine if water is an effective extinguishing agent.

For metals not listed in Table A.6.3.3, 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 fire fighters responsible for fighting fires at the facility.

A.9.4.13.15.7.11(A) An abnormally high pressure drop can indicate a significant build-up of material or blinding of the filters, which can create a hazard and decrease the flow rate and efficiency of the collection system.

A.9.4.13.15.7.11(C)(3) Some fire-extinguishing agents can cause an oxygen deficient atmosphere.

A.9.5 Permanently installed vacuum cleaning systems are preferred to portable vacuum systems as 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.

A.9.5.2 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.5.6 Utility vacuums or residential, automotive, hobby, or household portable vacuums should not be used.

A.9.5.6.1 Improper use of vacuum cleaners for combustible metal powder and dust accumulations can result in fire or explosion. For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

Typically, it is recommended that no more than 2.2 kg (5 lb) of dust should be collected at any one time before a vacuum cleaner is emptied. A vacuum cleaner should be checked to be sure that it is empty before each use. A vacuum cleaner should be emptied at the end of each use. *(See 7.5.4.)*

Improper use of vacuum cleaners for combustible metal powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.5.6.2 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.3.3.45.)*

The dust-separating unit should be cleaned unless it has been determined that the materials exhibit no incompatibility.

A.10.1.3 Chapter 5 of NFPA *101*, *Life Safety Code*, provides a more complete description of the performance-based design process and requirements. In addition, the SFPE *Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*, outlines a process for developing, evaluating, and documenting performance-based designs.

A.10.1.4 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.10.2.3 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.10.2.4.1 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.10.3.5(3) Deflagration vent operation does not constitute rupture of the equipment.

A.10.4 The risk evaluation conducted according to Section 4.7 might be useful in identifying the design scenarios for Section 10.4.

The fire and explosion scenarios defined in Section 10.4 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.10.4.1.1 A compartment is intended to include the area within fire-rated construction.

A.10.5.1 The SFPE *Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings* outlines a process for evaluating whether trial designs meet the performance criteria.

A.11.1 Finely divided dry alkali metals and finely divided alkali metals dispersed in a flammable liquid can exhibit pyrophoric properties. Prior to the handling of these materials, the vendor of the alkali metals, alkali metals alloy, or alkali metals dispersion should be consulted for safe practices. These practices include the design of the facilities for storage and handling of these materials, protective clothing requirements, training requirements, and general safety precautions.

Dry alkali metals and alkali metal alloy powders are pyrophoric in nature and water reactive. Precautions are required because, on exposure to air, the powders can ignite or explode.

Dispersions of alkali metals and dispersions of some alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to reactive metals, solvents present the concerns of flammable or combustible liquids and vapors. The SDS provided by the supplier of the material; NFPA 30, *Flammable and Combustible Liquids Code*; and NFPA 77, *Recommended Practice on Static Electricity*, are applicable to addressing the problems of combustible liquids and vapors.

Figure A.11.1 shows how the user would use Chapter 11 for alkali metals.

A.11.1.2.1 Alkali metals react with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction vary with the conditions; therefore, the best approach is to take precautions to keep moisture away from alkali metals.

A.11.1.3.1 Alkali metals in contact with moisture form alkali metal hydroxides and alkali metal oxides, which will cause caustic burns. Alkali metals in contact with human skin will react with body moisture and cause thermal and caustic burns.

A.11.1.3.2 Hazards involved with handling molten alkali metals are significantly greater than those involved with handling solid alkali metals due to enhanced reactivity, heat of reaction, and elevated temperatures.

A.11.1.3.2.2 Fire risk is significantly reduced when the outer clothing layer is kept dry.

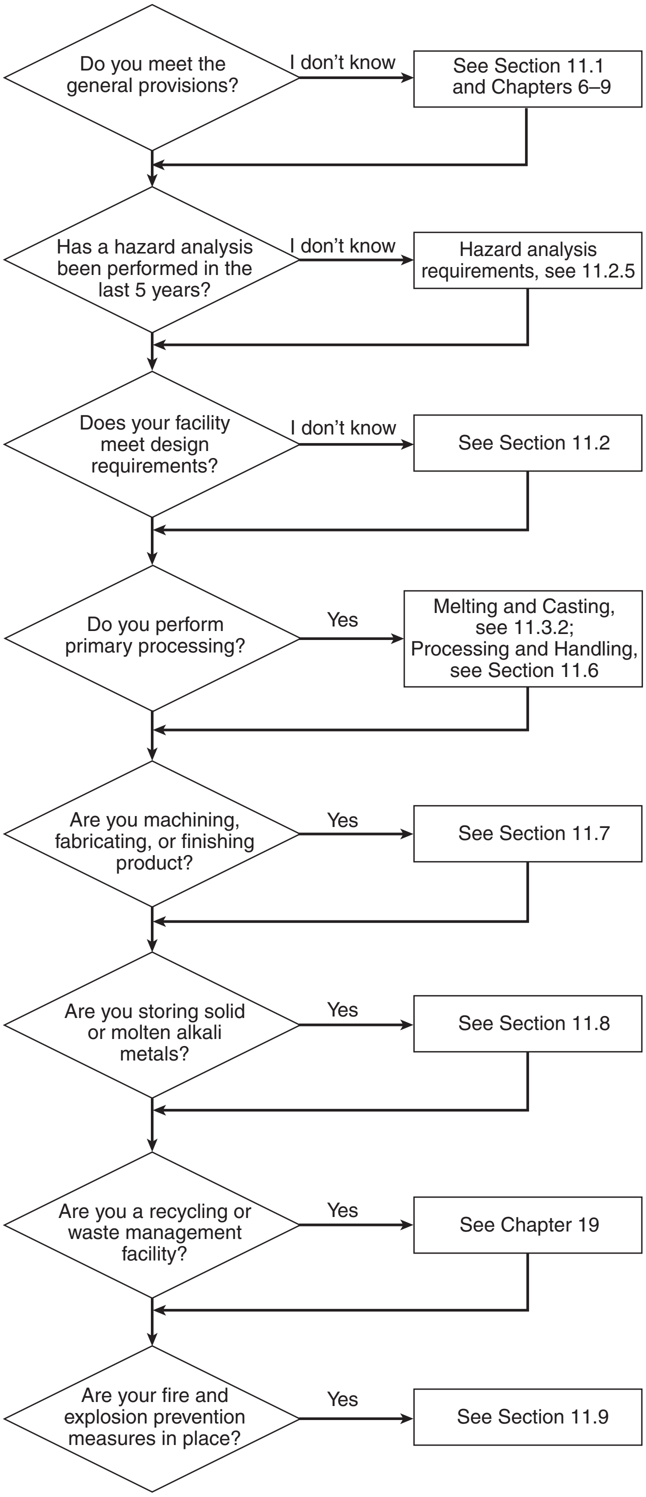


FIGURE A.11.1 Flow Diagram for Alkali Metals.

A.11.1.4.1 Thermite reactions are extremely exothermic, [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal which reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.11.2 Consideration should be given to automatic fire detection systems in alkali metal production plants to ensure life safety.

A.11.2.1.4 The requirement for watertight roof decks is an effort to ensure that buildings are designed and maintained to minimize possible leaks from weather conditions. Special care should be given to maintaining these roofs, especially in climates where heavy amounts of snow are expected.

A.11.2.1.6 Because of the potential presence of mineral oil on the floor, nonslip surfaces should be provided.

A.11.2.1.7 Floor drains typically are connected to systems that contain water, which when in contact with an alkali metal will result in a violent reaction.

A.11.2.1.9.1 Laboratories, bathrooms, and other areas not dedicated to the processing of alkali metals can have water leaks. Consideration needs to be given to preventing water from such leaks from entering the alkali metals processing areas and creating fire and explosion hazards.

A.11.2.1.10 A ridged or peaked roof that allows for natural ventilation of hydrogen is recommended.

A.11.2.2.2 The plan should include specific actions in the event of an alkali metal fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

The plan should pay special attention to the extreme hazards associated with alkali metal–water reactions that might occur with sprinkler water. Specific attention should be paid to an evacuation plan for personnel in the event of any release of water.

The particulate fumes given off by burning alkali metals are very corrosive; therefore, nonessential personnel in the vicinity should be evacuated to a safe distance, with special attention given to shifting winds. Where frequent alkali metals fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with alkali metals know its hazards. Such personnel will have the greatest ability to extinguish an alkali metal fire in its incipient stage. Training should include sufficient information to determine whether extinguishment can be accomplished safely and effectively.

An alkali metal at room temperature and in the presence of incompatible materials can reach its melting point and the autoignition temperature.

The degree of reaction and the amount of time to produce the melting point and autoignition temperature vary with surrounding conditions, with the temperature of the exposed alkali metals being the major factor. At low temperatures or temperatures within a few degrees of the melting point of the alkali metal, the reaction is slower and with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting an alkali metal fire, it is important that fire fighters be aware of the dangers of burning alkali metal. When molten alkali metal reacts with materials such as water or flammable or combustible liquids or gases, molten alkali metal can be ejected a considerable distance. The severity of alkali metal reactions varies with a multitude of conditions.

An alkali metal in contact with moisture and air forms alkali metal hydroxides and alkali metal oxides, which will cause caustic burns if personnel do not have adequate personal protective equipment.

A.11.3.2.1 Organic materials in the presence of oxides of potassium or NaK can create an explosive, shock-sensitive mixture.

A.11.6.1.1 Dispersions of alkali metals in organic solvents present special concerns. In addition to the water reactivity/pyrophoricity due to the reactive metal, solvents present the concerns of flammable or combustible liquids and vapors. The SDS provided by the supplier of the material; NFPA 30, *Flammable and Combustible Liquids Code*; and NFPA 77, *Recommended Practice on Static Electricity*, are applicable to addressing the problems of combustible liquids and vapors.

A.11.6.1.2.2 Organic materials in the presence of oxides of potassium or NaK can create an explosive shock-sensitive mixture.

A.11.6.1.2.3 Solid alkali metals are supplied in a variety of forms (e.g., ingots and ribbon), which are often individually protected in small cans or airtight foil pouches. If individual containers are not supplied and the containers are opened, alkali metal is exposed to surrounding air, causing slow reactions to take place. It is for this reason that, once the container is opened, only the amount of alkali metal intended to be used should be removed and the container should be immediately resealed.

A.11.6.1.2.4 If left open for more than 15 minutes, the container should be purged with a gas that is inert to alkali metals.

A.11.6.4.1.4 See A.11.8.1.2.1.3.

A.11.6.4.1.6 In the assessment of the amounts needed for process use, risks and fire exposures should be evaluated with other processing requirements. Alkali metals in containers staged for melting should be considered process vessels.

A.11.7 Section 11.7 applies to operations where alkali or alkali alloys are subjected to processing or finishing operations. The operations specified in Section 11.7 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

A.11.8.1 A number of small buildings or structures separated from each other, as opposed to a single larger building, reduce the risks associated with handling and processing alkali metals. In the event of an uncontrolled alkali metals emergency, property damage would be comparatively reduced.

A.11.8.1.2.1.1 Alkali metal is shipped from alkali metals manufacturers in UN specification containers that should continue to act as storage containers. Containers should be sealed to remain airtight, with the alkali metal coated with mineral oil or packed under an argon cover. Containers used to store alkali metals under mineral oil for long-term storage (over 3 months) should be inverted to redistribute the mineral oil covering the alkali metal. Containers packed under an argon cover should be checked regularly to verify the integrity of the container seal. When alkali metal is returned to any shipping container, the protective method used by the manufacturer should be duplicated.

A.11.8.1.2.1.3 Alkali metals are known to be incompatible with the following materials:

(1) Inorganic and organic acids
(2) Halon 1211
(3) Halon 2402
(4) Carbon tetrachloride
(5) 1,1,1-trichloroethane
(6) Oxidizers such as nitric acid
(7) Chromic acid
(8) Phosphoric acid
(9) Hypochlorous acid
(10) Reducing acids such as sulfuric, hydrochloric, and sulfamic acid
(11) Mineral oil for NaK
(12) Halogenated hydrocarbons
(13) Water
(14) Alcohols
(15) Carbon dioxide

Oxalic acid, phenol and organic acid mixtures, and compounds such as paint strippers or metal cleaners are also reactive and should not be stored in the vicinity of an alkali metal.

A.11.9 Alkali metal fire residue products can include metallic alkali metals, alkali metal nitrides, alkali metal oxides, or alkali metal hydroxides, which can absorb moisture.

A.11.9.1.1 Once an alkali metal fire is extinguished, alkali metal is usually still present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of alkali metals. Alkali metal fire residues can include other reactive components. These residues can react with each other and cause re-ignition. Containers of residues can be purged with argon gas, or the residues can be coated with water-free mineral oil to reduce the potential for reaction. Under solid waste environmental regulations, these residues could be considered a hazardous waste and could be subject to hazardous waste packaging, storage, notification, and disposal regulations.

A.11.9.2.2 Alkali metals react with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction vary with the conditions; therefore, the best approach is to take precautions to keep moisture away from alkali metals.

A.11.9.3.2.1 The longer the material is stored, the greater the risk of hazardous reactions.

A.11.9.4 Attention is called to the hazardous conditions that could exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around metal powder plants.

A.12.1 Figure A.12.1 shows how the user would navigate through this chapter on aluminum.

A.12.1.3 The use of eye, head, and respiratory protection (e.g., face shields, safety glasses, and hard hats) is recommended and should be determined by a PPE hazard assessment, as required by the Occupational Safety and Health Administration (OSHA).

A.12.1.4.2.1 The reaction of water and aluminum powder produces hydrogen. Hydrogen is extremely flammable and

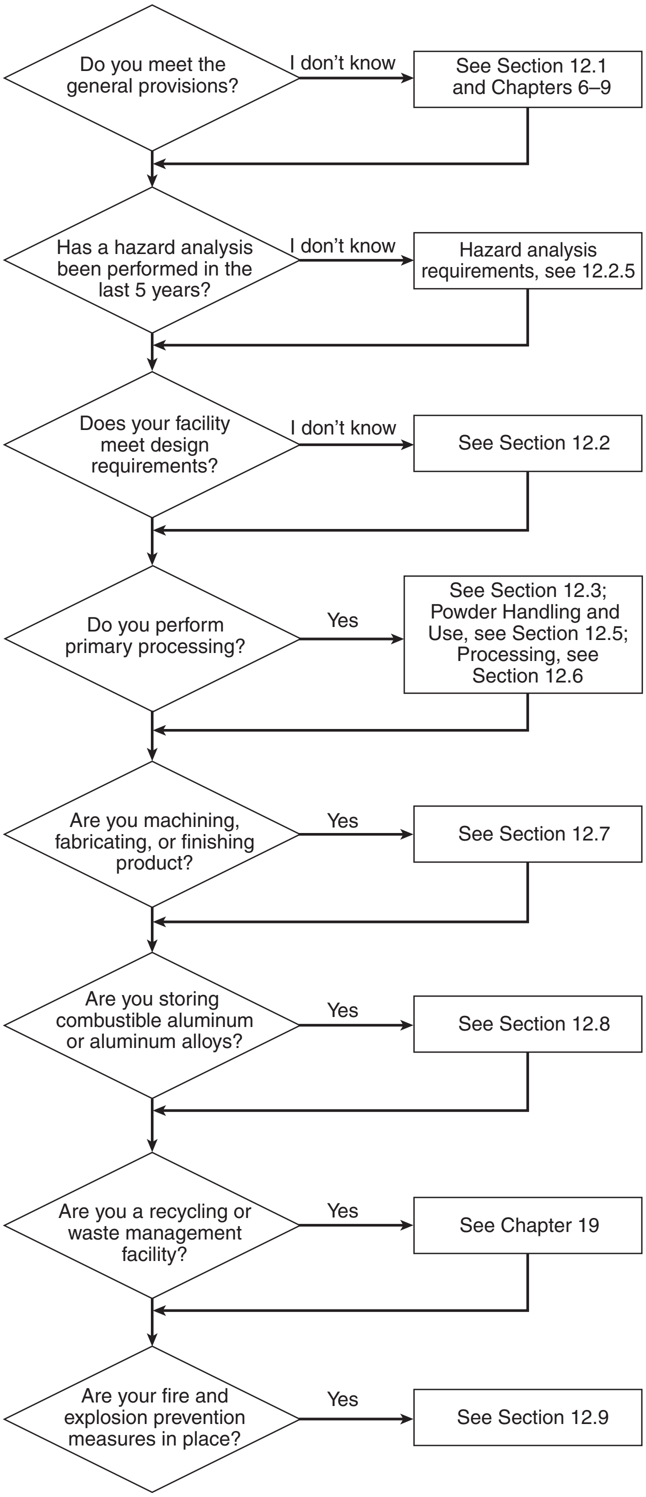


FIGURE A.12.1 Flow Diagram for Aluminum.

very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.12.1.4.3.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine aluminum particulate, especially powder, although there are documented instances of aluminum grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to aluminum and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with aluminum have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.12.2.1.9 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.12.2.1.16 See Section 5.11 and Chapter 28 of NFPA *101*, *Life Safety Code*.

A.12.2.1.17.1 For information on deflagration venting, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.12.2.2.1.1 Because it is almost impossible to extinguish a massive fire in dry aluminum powder, the fire problem can be effectively resolved only by controlling such a fire in the incipient stage. The requirements of 12.2.2.1 should be followed if the fire is to be controlled quickly. This is especially true with regard to the application of the extinguishing material, because even a minor dust cloud can explode violently.

A properly ringed fire will develop a hard crust of metal oxide that will ultimately exclude enough oxygen to cause self-extinguishment. It is customary practice, after dispensing the extinguishing material, to leave the area, closing all doors leading to the area and sealing them with sand. The area should not be re-entered until combustion has stopped and the material has cooled.

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 aluminum 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 nonsparking metal should be provided at each such receptacle to afford a ready means of laying the material around the perimeter of the fire.

Nearly all vaporizing liquid–fire-extinguishing agents react violently with burning aluminum, 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.12.2.2.1.4 Experience has shown that dry sodium chloride is one of the most effective chemicals for containing fires involving aluminum. Fire-fighting salts should be checked periodically to ensure that they have not become caked from moisture. Another effective chemical is a nonmetallic flux compound consisting of potassium chloride, magnesium chloride, and calcium fluoride. Commercial dry-powder fire extinguishers or agents approved for use on combustible metals are also effective. Covering the fire completely reduces the accessible oxygen supply, thereby slowing the burning rate so that eventual extinguishment is reached.

A.12.2.2.2.3 Class B extinguishing agents will usually greatly accelerate combustible aluminum dust fires and can cause burning metal to explode.

A.12.2.2.2.4 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 are provided also. 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 characteristic 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.12.2.2.2.4.2 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.12.2.2.2.5.1 Re-ignition can occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

A.12.2.2.2.5.3 Materials preferably should be handled in quantities of not more than 11 L (3 gal) each in 19 L (5 gal) containers.

A.12.2.2.3.6 For guidance on design criteria for fire flow containment, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.12.2.2.4.1.1 For the automatic sprinkler provisions for storage and use of flammable and combustible liquids, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.12.5.1.3 Certain non-dusting grades of aluminum flake powder are being produced. These powders tend to reduce the hazard of inadvertently caused dust clouds. They are as combustible as regular grades of flake powder and, once levitated into a cloud, exhibit the same explosibility characteristics. For those reasons, the same precautions must be observed as for normal grades of powder.

A.12.6.1.3 This requirement is applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled, such as in finishing and polishing equipment, filters, driers, dust screens, fixed storage bins, and dust collection and transport systems of all types. For further information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.12.6.1.4.1 Journal bearings should not be used because of the difficulty of maintaining proper lubrication to prevent overheating. Outboard bearings are used where practicable because it is easier to check for overheating. In those instances where dust tends to penetrate bearings, a continuous flow of inert gas (1½ percent to 5 percent oxygen) can be employed to pressurize the bearings and seals.

A.12.6.2.1.1 When aluminum is milled in a ball or rod or similar type of mill in the presence of a liquid that is chemically inert with respect to the metal, the air–dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air, any unoxidized surfaces produced during milling will react and could generate enough heat to cause ignition. To prevent ignition, it is imperative that a controlled amount of oxygen be present in the milling operation and in slurries ahead of filters and blenders, so that new surfaces are oxidized as they are formed. The addition of a milling agent, such as stearic acid, does not eliminate the need for this added oxygen.

A.12.6.2.1.1.1 See A.12.6.2.1.1.

A.12.6.2.1.1.2 See A.12.6.2.1.1.

A.12.6.2.1.1.5 Of particular note in the aluminum paste–manufacturing process are the risks associated with hybrid mixtures. A hybrid mixture is a mixture of a dust with one or more flammable gases or vapors. The presence of a flammable gas or vapor, even at concentrations less than its LFL, not only will add to the violence of the dust–air combustion but will drastically reduce the ignition energy. In such cases, electrical equipment should be specified that is suitable for simultaneous exposure to both the Class I (flammable gas) and the Class II (combustible dust) hazards.

A.12.6.4.1 See Figure A.12.6.4.1(a) and Figure A.12.6.4.1(b) for examples of dust collection at bag dump stations.

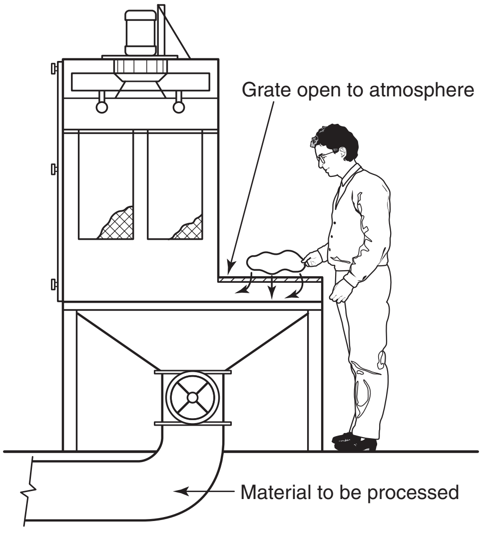


FIGURE A.12.6.4.1(a) Example of Unacceptable Manual Bag Dump Station in Which Operator Is Exposed to Potential Fire or Explosion.

A.12.7 Section 12.7 applies to operations where aluminum or aluminum alloys are subjected to processing or finishing operations. The operations specified in 12.7.1.1 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids.

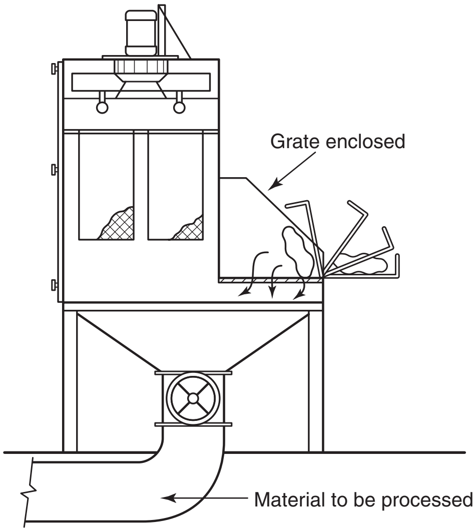


FIGURE A.12.6.4.1(b) Example of Acceptable Station in Which Bag Dump Operation Is Automatic.

A.12.7.3.2 If a sufficient coolant flow is not used, improperly designed or dull tools can produce high temperatures at the tool–workpiece interface, potentially causing ignition of the turnings.

A.12.7.3.3 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.12.7.3.5.1 Cutting oils with a flashpoint greater than 200°F are acceptable with some combustible metals; however, oil-based fluids are rarely seen anymore due to environmental issues. Most water-based fluids are adequate from a quality control and fire standpoint. Most oil-based fluids are used on steel tool machining (drill bits, shears, etc.) due to the lower risk of corrosion.

A.12.8.1.4 Materials incompatible with aluminum powder include, but are not limited to, oxidizers, organic peroxides, inorganic acids, and materials identified in the SDS.

A.12.9.5.2 Employee health and safety in operations depend on the recognition of actual or potential hazards, the control or elimination of those hazards, and the training of employees on safe working procedures.

A.12.9.5.3.2 The following are important elements of employee training:

(1) All employees should be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.
(2) All employees should be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire-extinguishing equipment.
(3) All employees should be taught the permissible methods for fighting incipient fires in pastes and for isolating aluminum fires.
(4) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire should be explained.
(5) Strict discipline and scrupulous housekeeping should be maintained at all times.

(6) Attention should be given to employee training and organizational planning to ensure safe and proper evacuation of the area.

A.13.1 Figure A.13.1 shows how the user would navigate through this chapter on magnesium.

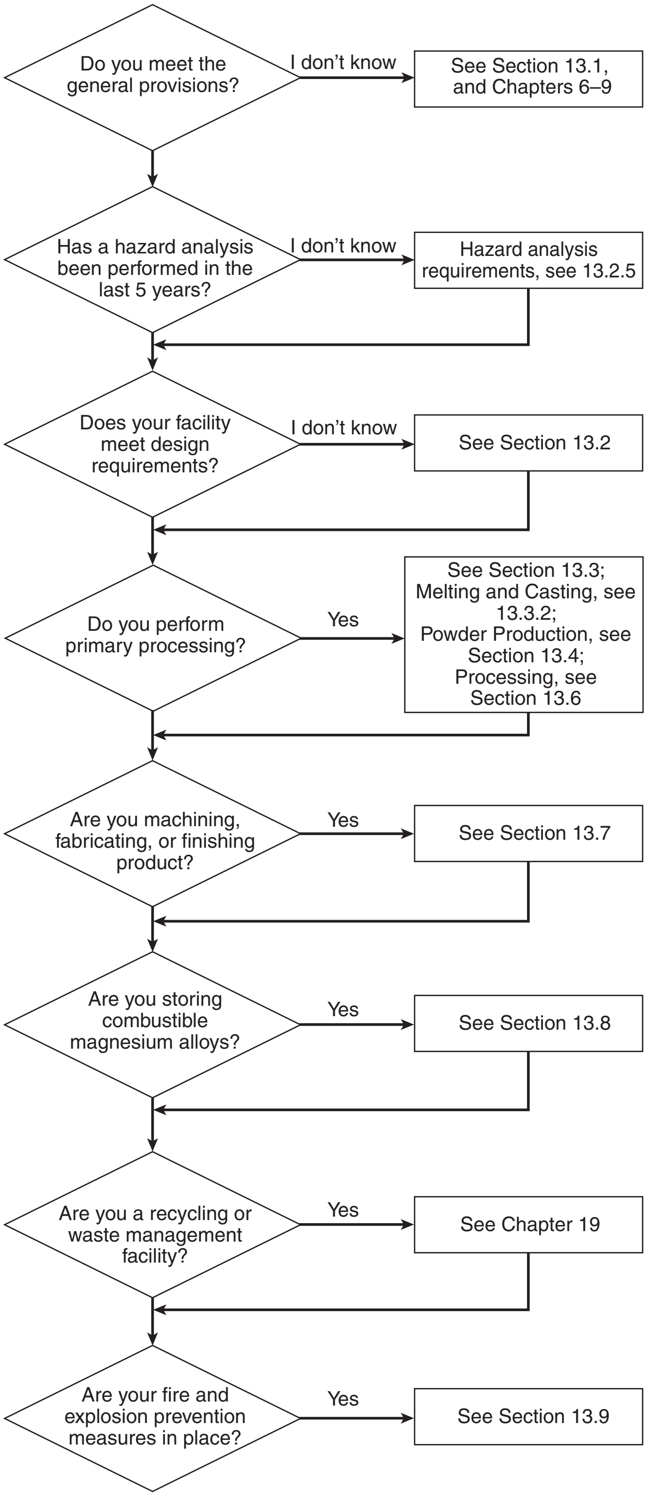


FIGURE A.13.1 Flow Diagram for Magnesium.

A.13.1.4.1.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.13.2.1.1.11 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.13.2.1.1.16.3 See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.13.2.1.1.17 See NFPA 77, *Recommended Practice on Static Electricity*.

A.13.2.3 See NFPA 77, *Recommended Practice on Static Electricity*.

A.13.3.2 Chips, turnings, powders, or swarf that is being preheated or charged to melting pots will auto-ignite at temperatures below that of the solid metal. Solids should be free of these smaller particles, which can ignite and, in turn, ignite the solids. There should be no depression directly beneath the magnesium storage area where water can accumulate or flow during a fire.

A.13.3.2.1.2 Because concrete always contains water, concrete in contact with hot materials such as molten magnesium can result in an extremely violent reaction, including violent spalling of concrete.

A.13.3.2.2 The contact of moisture with molten magnesium metal can result in a violent explosive reaction with the generation of steam or hydrogen. It is important to establish and document a method of preheating that heats all material to a minimum temperature of 121°C (250°F) to ensure the removal of moisture. A higher heating temperature might be necessary if the metal is contaminated with corrosion products, salts, or other foreign materials. Molds or tools that will come into contact with molten magnesium should be similarly preheated.

A.13.3.2.4 Iron scale and molten magnesium 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.

A.13.4.1.4 Temperature-sensing elements connected to alarms or machine stop switches can be employed for locations where overheating of bearings or other elements is anticipated.

A.13.4.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.13.4.2.3 Bearings located outside the air volume containing magnesium dust are preferred. Bearings within the air volume containing magnesium dust are potential sources of ignition in the event of a failure.

A.13.4.6.1.1 Special attention is necessary to ensure that the magnesium powder is not exposed to moisture.

A.13.7 Section 13.7 applies to operations where magnesium or magnesium alloys are subjected to processing or finishing operations. The operations specified in Section 13.7 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

A.13.7.2.1 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A.13.7.4 Flashing of chips during machining should be minimized by any of the following methods:

(1) Keeping the surface speed below 1.5 m/sec (300 ft/min) or above 11 m/sec (2200 ft/min)
(2) Increasing the feed rate from 0.02 mm to 0.25 mm (0.0008 in. to 0.010 in.) per revolution
(3) Controlling the relative humidity in the machining area to 45 percent or lower at 21°C (70°F) room temperature
(4) Applying a coolant

A.13.7.4.2 Use of high-helix drills prevents frictional heat and possible flash fires in fines. High-helix drills are also recommended for drilling deep holes through composite or sandwich sections.

A.13.7.5.3 Standard commercial industrial vacuum cleaners should not be used, because they are not safe for use with magnesium.

A.13.7.6 Special precautions are necessary to prevent ignitions during dressing of the wheels used for grinding magnesium castings. Hot metal thrown off by the dressing tool can ignite dust or magnesium deposits in the hood or duct.

A.13.7.8 Heat treating of magnesium has associated fire risks. To retard ignition of magnesium, mixtures of sulfur dioxide (SO_2), sulfur hexafluoride with carbon dioxide (SF_6/CO_2), helium (He), and argon (Ar) with air are recommended in heat treating furnaces operating above 399°C (750°F).

A.13.7.8.3 See NFPA 86, *Standard for Ovens and Furnaces.*

A.13.7.8.4.2 The secondary set of temperature controls should cut off fuel or power to the heat-treating furnace at a temperature that is only slightly above the desired operating temperature.

A.13.7.8.7 Extreme care should be taken when heat treating aluminum that contains magnesium alloys, because aluminum additions form a eutectic alloy with considerably lower melting and autoignition temperatures. Failure to identify the alloy can result in heat-treating furnace fires. Magnesium in physical contact with aluminum at an elevated temperature can produce the same effect.

A.13.7.8.9 Heating magnesium in the presence of oxidizers can result in combustion. Special salt fluxes can be safely used for dip brazing of magnesium.

A.13.7.8.10 Magnesium and aluminum form a eutectic alloy with considerably lower melting temperatures and autoignition temperatures than either parent metal.

A.13.7.8.11 There is a potential for a thermite reaction between magnesium or a magnesium alloy and iron oxide at elevated temperatures.

A.13.8.1.1 Industrial buildings or separate storage areas in which magnesium parts are being stored in quantities greater than 227 kg (500 lb) or where these magnesium parts are the primary hazard should be labeled in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response.* The labeling serves as a warning to fire fighters on the potential risk in the event of an emergency.

A.13.8.1.1.3 Storage of magnesium ingots should be on the first or ground floor. Basements or depressions below the magnesium storage area into which water or molten metal can flow should be avoided.

A.13.8.1.1.3.4(B)(2) See NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, for wall construction details.

A.13.8.1.2.3 Storage of magnesium castings should be on the first or ground floor. Basements or depressions below the magnesium cast storage area into which water or molten metal can flow should be avoided.

A.13.8.1.2.7 Sprinkler systems are of vital importance in heavy magnesium casting areas that also contain significant amounts of ordinary combustibles, because sprinkler operation can prevent the magnesium from becoming involved in the fire.

A.13.8.1.3.5 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium and produce a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be 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, *Standard for the Installation of Sprinkler Systems.*

A.13.8.1.5.4 The wet magnesium should be checked frequently to ensure that it remains totally immersed during storage.

Fines that come in contact with water, water-soluble oils, and oils containing more than 0.2 percent fatty acids can generate flammable hydrogen gas. Fines that come in contact with animal or vegetable oils can ignite spontaneously.

A.13.8.1.6.6 The safest manner of storage is achieved using no stacking.

A.13.8.1.7.1 Because the magnesium portions of parts and components can exhibit the burning characteristics of magnesium when involved in a fire, storage plans and arrangements should be designed to mitigate the fire hazards associated with burning magnesium.

Assemblies in which magnesium is a minority component might or might not exhibit burning behavior similar to a fire involving pure magnesium, depending on the following:

(1) Whether or not the magnesium is exposed on the outside of the assembly
(2) How fast or how completely the packaging material might burn away to expose the magnesium
(3) Height and arrangement (removed intentionally)
(4) Intensity of any exposure fire

(5) Rapidity with which automatic protection systems might respond to control the initial fire, thus preventing the involvement of the magnesium

The best method to determine the level of hazard is by a properly designed fire test.

A.13.8.1.7.4 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium and produce a well-involved magnesium fire before automatic sprinklers operate. Special importance, therefore, should be 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, *Standard for the Installation of Sprinkler Systems*.

A.13.9.3 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.13.9.4.3 Special attention should be given to the segregation of ordinary trash and the routine collection of sponge, chips, and powder from floor sweepings as a function of housekeeping.

A.14.1 Figure A.14.1 shows how the user would navigate through this chapter on niobium.

A.14.1.4.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.14.2.1.3.1 Niobium metal powder can be extremely sensitive to ignition from electrostatic discharge. The specific level of risk is dependent on the specific character of the powder being handled. High-surface-area niobium powders possess a level of sensitivity far in excess to those of much lower surface area and coarser particle size distribution. An effective strategy for flooring should reflect the level of risk associated with the materials being handled in the facility. If the niobium powder is in combustible form (see Chapter 4), static-dissipative flooring should be employed.

A.14.2.1.4 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.14.2.1.6.9 In some niobium-processing operations, process equipment requires cooling water. Under those circumstances, a hazards operations review should be conducted on the site and locations to determine where to feed the water. Water pipes necessary for providing cooling water should be located in such a fashion that they minimize their exposure to areas where it is determined that the risk of a niobium fire is greatest. It is recognized that niobium powders can be ignited by exposure to hot surfaces. As such, the use of cooling water in a judicious manner is deemed as a means by which hot surfaces can be reduced or eliminated.

A.14.2.1.7.2 Portable processing equipment should be constructed in such a fashion that grounding can be readily

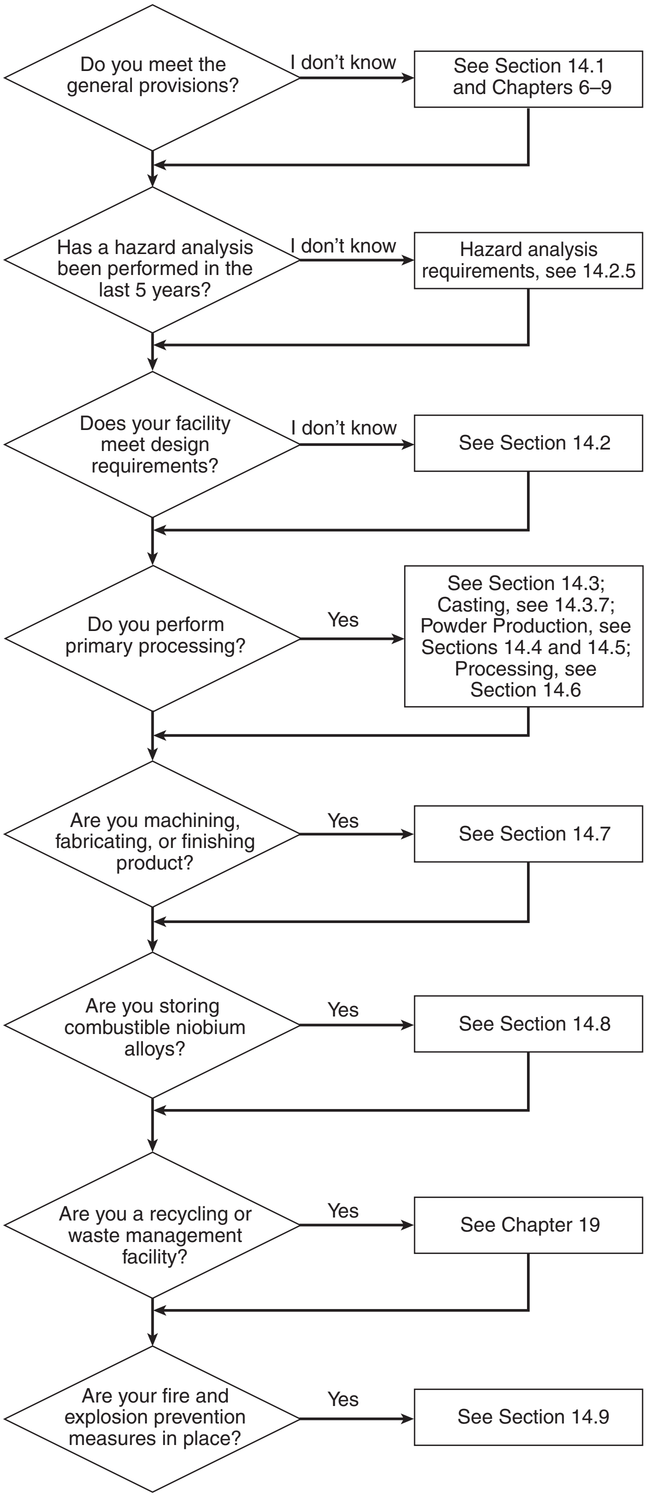


FIGURE A.14.1 Flow Diagram for Niobium.

accomplished. For instance, metal carts should have static-dissipative wheels. Even with antistatic 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.

Additionally, the risk of electrostatic discharge as a potential ignition source for niobium powders can be very high (MIE can be less than 3 mJ). Though theoretically possible, brush discharge from insulating materials has never been identified as an ignition source for niobium dust clouds. Spark discharge from conductive materials represents the far greater risk. In complex installations of machinery and equipment, the danger of the occurrence of an isolated conductor is possible. It is, therefore, 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.

A.14.2.1.7.3 It is recommended that a periodic test program be instituted to monitor the level of resistance to earth ground as well as to ensure that the integrity of fixed grounds remains acceptable. The need to ensure that grounding criteria are satisfied becomes more urgent as finer-particle-size 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 niobium powders being processed.

A.14.2.1.8.2 The design of deflagration venting should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.14.2.1.8.3 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 of 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, *Standard on Explosion Protection by Deflagration Venting*.

Deflagration vent closures should be designed such that, once opened, they remain open to prevent failure from the vacuum following the pressure wave.

A.14.2.1.8.4 For further information on restraining vent closures, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.14.3.4 Because of niobium's strong affinity for oxygen and its tendency to become contaminated, niobium is melted under vacuum or inert gas using water-cooled copper crucibles to contain the molten metal. Partial vacuums are maintained by introduction of argon, helium, or mixtures of inert and reactive gases to the melting chamber.

Since the early 1950s, several titanium-melting furnaces have experienced explosions after water inadvertently entered the melting crucibles during the melting operation. Niobium and titanium both have a very high affinity for oxygen, which is one of the fundamental causes of melting furnace explosions. While there have been no reported niobium-melting furnace explosions, it is understood that the potential exists for an incident. Investigations of the titanium incidents have determined that the following three distinct events working together are responsible for melting furnace explosions:

(1) Rapidly increasing pressure created by water making contact with the molten metal. This is the first phase of furnace explosions. The tremendous pressures generated can result in severe damage to the melting chamber and subsequent paths for the introduction of air into the chamber.
(2) Reaction of the water with the molten niobium liberating hydrogen gas, the volume of which is dependent on the volume of molten metal in the crucible and the amount of water introduced. The generation of the hydrogen gas in itself does not produce a violent reaction or explosion but creates a potentially hazardous condition in the furnace chamber.
(3) Introduction of air as a result of furnace vessel failure or by operation of valves, doors, or other equipment, which can result in an explosive mixture of hydrogen and oxygen. This explosive mixture can be ignited by the residual heat in the melting crucible.

The sequence of the events is thought to be as follows:

(1) Steam explosion
(2) Generation of hydrogen gas
(3) Introduction of air into the chamber
(4) Ignition/explosion of hydrogen–oxygen gas mixture

However, a steam explosion by itself can do severe damage, as would an explosion of a hydrogen–oxygen gas mixture. The explosion hazard is present in any niobium-melting furnace that uses water-cooled crucibles.

A.14.3.4.1 Entrance of water into the furnace chamber is the primary cause of both steam and hydrogen explosions. Features to reduce or eliminate the entrance of water into the furnace chamber should be incorporated into the design of new equipment or modifications to older equipment. Examples are the use of NaK for cooling media, which has hazards of its own to consider. Newly created hazards should be weighed against the hazards potentially eliminated before incorporating the changes in practice.

A.14.3.4.2.1 The furnace and crucible assembly should be located in a protective bunker that will direct the explosion away from operating personnel in adjacent areas. Isolation of the furnaces and remote operation remove the operating personnel from the immediate vicinity of the furnace and reduce the risk of severe injury if an explosion occurs.

A.14.3.5.1 The explosion that can occur due to the rapid phase transformation (liquid to gas) of water trapped below molten metal takes place over a span of 10^{-5} second to 10^{-4} second. This time span is faster than a condensed phase detonation. The required pressure-relieving device would not be effective in relieving the rapid pressure buildup caused by the rapid transformation of water trapped below molten metal. The required device is intended to safely relieve only a much slower buildup of pressure, such as might occur from small incursions of water onto the surface of the molten metal.

A.14.3.5.4 In vacuum arc remelting furnaces, arcing of the electrode to the mold wall is the primary cause of water being introduced into the chamber. To minimize the risk of arcing, the electrode should be straight and of uniform cross section to maintain the clearance between the electrode and the mold wall. Additionally, use of magnetic fields should be considered to deflect the arc away from the mold wall.

Use of an electromagnetic field to contain the arc and to prevent arcing to the crucible is standard practice in vacuum arc remelting.

A.14.3.5.5 Sudden rises in pressure are an indication of the onset of a steam or hydrogen–oxygen explosion in the furnace. The normal operating range and rates of rise in pressure for the process should be determined as part of the process control function. High-pressure and rate-of-rise-in-pressure interlocks should be installed to shut off the power to the process when they are activated. Continuation of heat to the process will continue the generation of molten niobium and result in more hydrogen or steam, or both.

The process operating parameters should be continuously monitored for abnormal conditions. Waterflow, temperature, and pressure on the cooling system are critical for maintaining the correct cooling conditions. Furnace pressure can provide early warning of abnormal conditions in the furnace chamber. Use of data acquisition to monitor the process is the most effective way to oversee the many parameters that could be of interest. Automatic alarms that warn operators of abnormal conditions are also beneficial. Where a parameter is deemed critical or an indicator of an extreme safety hazard, the use of interlocks to terminate the process is the best course of action.

A.14.3.5.6 Hazards analyses can be used to determine the minimum thicknesses required for safe operation. Several catastrophic incidents have occurred due to failure to prevent the interaction between molten metals and water.

A.14.3.6 Loss of water supply to the crucible will result in a meltdown of the copper crucible and subsequently to the entry of water into the furnace chamber. If the normal water supply fails, an emergency water supply system should automatically be activated. Activation is best achieved with a low–water pressure interlock that activates the emergency water supply if the water pressure falls below a prescribed level.

A.14.3.7.2 The collection of moisture in a mold could cause the niobium to react, causing a fire or explosion.

A.14.3.7.2.4 Locating control consoles away from the immediate vicinity of melting furnaces reduces the risk of injury if an explosion occurs. The distance from the furnace should be determined on a case-by-case basis by assessing the potential, magnitude, and expected path of the explosion. The best sources of technical expertise are the furnace manufacturers, which should consider the issue of remote location of control consoles for any new or modified niobium melting furnace.

A.14.3.7.3 Furnace residues produced in a vacuum or inert gas atmosphere are finely divided powders that have not been exposed to an oxidizing atmosphere. Niobium has a high affinity for oxygen and will oxidize until a sufficiently thick oxide layer has formed. If the oxide layer is formed in a controlled manner, the process is called passivation. If the oxide layer is formed in an uncontrolled manner, it simply burns due to the exothermic nature of oxidation of niobium.

Condensed furnace residues, by nature, are extremely fine on the order of submicron size and, hence, will oxidize more rapidly and generate more heat than powders with large particle size distributions.

After the furnace has cooled to ambient temperature, the use of passivation cycles, in which controlled amounts of air are introduced into the furnace, will render the material stable. An alternative is to burn the material completely while it is contained in the furnace, followed by cooling to ambient temperature. Burning will result in the complete oxidation of the residue and eliminate the potential for further oxidation.

After passivation or burning of the furnace residues is completed, the material should be placed in covered drums and moved to a designated safe storage location.

A.14.3.9 The same basic prevention measures apply to both niobium fires and explosions in mill operations. The prevention measures are good housekeeping, elimination of ignition sources, isolation of dust-producing operations and subdivision of large operations, and education of employees regarding hazards.

The basic protection measure against fire hazard is the automatic protection equipment. An important consideration is the ability of the fire protection system to function after an explosion. Suppression systems detect the explosion, suppress it, and extinguish it before dangerous pressures are developed. The pressure wave of an explosion travels at 33.5 m/sec (110 ft/sec), which puts it well ahead of the flame front, which travels at 1.2 m/sec to 1.8 m/sec (4 ft/sec to 6 ft/sec.) The equipment for suppression consists of the pressure detector, control unit, and appropriate extinguishing agent. The suppressant should block inlets and outlets as well as flood the vessel.

Inerting is the preferred approach for protecting against fire and explosion because it does not allow ignition to occur. Inerting consists of lowering the oxygen concentration below the point where it can support ignition. A successful inerting system requires a good method of control to insert the inerting gas into the process, as well as a continuous oxygen analyzer to monitor and shut down the system.

Mill operation processes are a source for the accumulation of niobium fines, saw chips, dust, and oily metallic scrap and residue. Ignition sources can be electrical, thermal, or mechanical, or static electricity can be the source.

The control of ignition sources is paramount in maintaining a fire-free environment. The following measures provide guidance for controlling ignition sources:

(1) Open flames and smoking should be prohibited.
(2) Cutting and welding in the vicinity of fines, dust, and flammable lubricants should be prohibited.
(3) Electrical equipment, wiring, and lighting in the area should be explosionproof, conforming to National Electrical Manufacturers Association (NEMA) rating class II, Group E, as defined in *Guide for Classification of All Types of Insulated Wire and Cable.*
(4) Blowers and exhaust fans should be suitable for the application. Maintenance should be provided to ensure clearance between the blades and the casing.
(5) All equipment should be grounded and bonded to prevent accumulation of static electricity. Electrical grounding of all equipment and containers should be thorough. Static cannot be grounded through an oil or grease film in bearings; therefore, it is necessary to provide wire jumpers around lubricating films.

(6) Sparks caused by metal striking metal should be eliminated.
(7) All sources of mechanical friction should be minimized.
(8) Magnetic separators or screens should be provided to prevent foreign objects from entering grinders, pulverizers, crushers, or milling equipment.
(9) Nonsparking types of tools should be used. Friction caused by hammering, sliding, or rubbing should be avoided.
(10) Individual dust collection systems should be provided for each piece of equipment as much as practical.
(11) Dust-handling equipment should be located adjacent to exterior building walls. Locations in basements should be avoided.

A.14.3.9.1 The principal fire hazard is the ease of ignition of finely divided combustible material with subsequent ignition of less easily ignited particles.

A second critical source of fire hazards comes from vapors and gases generated by lubricants and solvents used in the processes found in mill operations. The explosion hazard of a dust or vapor is an extension of a fire hazard and can be the source of ignition for niobium fires. Materials used in mill operations should be evaluated for their susceptibility for ignition in a mill operation environment.

A.14.3.9.2.4 Improperly designed or dulled tools can produce high temperature at the tool–metal interface, causing ignition of the turnings if an adequate coolant flow is not used.

A.14.3.9.2.5 Only mill lubricants with high flash points that come into direct contact with the processed metal pose a fire potential at any time the metal heats up to high temperatures in a mill environment in excess of the flash point of the lubricants.

A.14.3.9.2.6 Petroleum oils in any form are susceptible to relatively low ignition temperatures from any source in a mill environment. Practices that prevent ignition should be followed.

A.14.4.2 The quantity of niobium powders stored in manufacturing operations and areas should be minimized. The quantity should be limited to that needed to continue the operation or process.

A.14.4.6.1 All but the coarsest niobium powders oxidize readily at temperatures above 80°C (176°F).

A.14.4.6.3 If inert atmosphere drying or vacuum drying are chosen as the most appropriate styles of drying, care must be taken to ensure that the niobium powder is cooled below 80°C (176°F) prior to re-exposing the powder to air atmosphere. Heated powder oxidizes at a high rate when exposed to air at elevated temperatures.

A.14.4.7 Care should be exercised in selection of the type of dryer used to dry niobium powders. Electric resistance-element dryers should not be used due to the risk of niobium dust particles coming in contact with the heating elements and igniting. If dryers are outfitted with glass windows for the viewing of dryer contents, such windows should be covered with metal mesh reinforcement or external shielding to prevent the possibility of glass projectiles or other missile hazards resulting from an explosion. Dryer types include tray, drum, rotary, fluidized-bed, pneumatic, spray, and vacuum types.

Additionally, a hazards analysis should be conducted to determine the safest method of drying based on the specific materials being dried. Fine surface-area niobium powders are very sensitive to self-heating. Coarse-particle-size niobium powders are much less sensitive to drying conditions. Drying parameters — both the type of drying and the specific conditions of drying [i.e., temperature, bed height, drying gas atmosphere (air atmosphere or inert gas)] — need to be assessed in light of the specific powders to be dried.

A.14.4.7.3 Consideration should be given to a hazard analysis for a wet collection system installation.

A.14.4.7.6 Dryer control systems are critical components that provide safety during drying operations. The reliability of the microprocessor controllers should be checked and inspected on a regular basis (e.g., daily or weekly). Temperature overshoots can result in dangerous conditions that might allow dryer chamber temperatures to exceed 80°C (176°F). The reliability of thermocouples and fan controls should also be inspected on a regular basis to ensure correct and safe operation.

A.14.4.7.8(5) When niobium powder is dried in atmospheres containing oxygen, it is recommended that the dryer be outfitted with a means to allow the introduction of an inerting agent. Because niobium powder undergoes, under certain conditions, a highly exothermic reaction with nitrogen, nitrogen is not an appropriate inerting agent. The inerting agent of choice is argon or helium. Because of dryer design and configuration, it is sometimes difficult and awkward to use other appropriate extinguishing materials in the event of a niobium dryer fire. Historically the use of argon gas in extinguishing a niobium fire has proven to be very effective.

A.14.4.12.1 Controlling the generation and accumulation of niobium fugitive dust is of critical importance, owing to the specific nature of niobium metal powders. The minimum explosible concentration (MEC) for certain niobium powders (high surface area) is very low, and the K_{St} values can be very high. For those reasons, controlling and preventing dust clouds of niobium powder are important in preventing the possibility of a deflagration.

A.14.4.12.4 Refer to NFPA 77, *Recommended Practice on Static Electricity.*

A.14.4.12.7 The presence of moisture in air reduces surface resistivity of many materials in process areas where niobium powders are handled, thereby reducing general electrostatic discharge (ESD) ignition risk.

A.14.4.14.1 Explosion venting is especially important for combustible niobium 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, *Standard on Explosion Protection by Deflagration Venting.* Dust collectors, when provided by a manufacturer, seldom have properly sized venting to handle a combustible niobium dust explosion.

In processes where the component part consists of a variety of materials and it is not possible to segregate the combustible metal component during the finishing process, it should be noted that this mix of metals presents an additional hazard in the process ventilation equipment. Daily inspection, cleaning, and general maintenance of the system must be performed to minimize exposure to inherent risks when performing finishing procedures on these types of parts.

All equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity.*

A.14.4.14.2(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting.* For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The length of the relief duct should be restricted to not more than 6 m (20 ft).

A.14.4.14.2(3) Ductwork provided with explosion isolation systems identified in NFPA 69, *Standard on Explosion Prevention Systems*, which can prevent propagation of a deflagration into other parts of the process, is not subject to NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.14.4.14.2(5) This method is limited in effectiveness because of the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A.14.4.15 The use of inert gas for all machinery is highly recommended. All typical operations encountered in the processing of tantalum powder produce ignition sources (mechanical friction, impact sparks, hot surfaces, and potentially electrostatic discharge). As such, the primary basis of safety should be the exclusion of oxygen from the atmosphere under which niobium powder is processed.

A.14.4.16.1 Where personnel are working on suitable antistatic or conductive flooring, they should be wearing appropriate footwear. Footwear having resistance in the range of 1×10^6 ohms to 1×10^8 ohms is considered to be antistatic. Generally, it is recommended that personnel limit the conductivity of their footwear to the range of 5×10^{-4} ohms to 1×10^8 ohms. This accomplishes grounding of static discharge from the operator but reduces the potential risk of electrocution. All personnel should be electrically grounded when they are working in an environment containing a material possessing an MEC of 100 mJ or less.

A.14.4.16.4 Unauthorized personnel should not be permitted in powder-handling areas. Identifying authorized personnel is a decision made by the individual company. Authorized personnel are people experienced and knowledgeable in hazards associated with niobium powders. The intent of the requirement is to prevent people who are not familiar with the hazards associated with niobium powders from wandering through a production area. This requirement does not preclude such a person from being escorted by authorized personnel.

A.14.5.4 Static-dissipating flooring is often employed in niobium manufacturing and processing plants. However, it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available methods. Careful examination of the details of this standard will disclose the logic of the use of conductive flooring materials.

The surface of a static-dissipating floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges.

The maximum resistance of a static-dissipating floor is usually less than 10^6 ohms, as measured between two electrodes placed 0.9 m (3 ft) apart at any points on the floor. The minimum resistance is usually greater than 2.5×10^4 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks. Resistance values are checked at regular intervals, usually once each month.

Refer to *NFPA 70, National Electrical Code*, for equipment and procedures that are acceptable practice for testing for minimum and maximum resistance. Measurements should be made at five or more locations in each room, and results can be averaged.

For compliance with the maximum resistance limit, the average of all measurements should be less than 10^6 ohms.

For compliance with the minimum resistance limit, one individual measurement should be less than 10^5 ohms, and the average of not fewer than five measurements should be greater than 2.5×10^4 ohms.

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 0.9 m (3 ft) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

A.14.5.5 The following are considered spark resistant and appropriate for use with niobium:

(1) Beryllium-copper
(2) Brass
(3) Phosphorous bronze

Aluminum should not be used because of the potential for thermite sparks. Thermite sparks can occur with aluminum, magnesium, tantalum, titanium, or their alloys in the presence of oxygen carriers such as iron or lead oxide. Thermite sparks are highly incendive (and energetic) sparks that are white hot.

In the manufacture of product from niobium powder, it might be necessary to mix the niobium powder with other additives or to pour the niobium powder from one container to another. Both of these operations tend to produce a niobium dust cloud. A hazards analysis should be done on any operation that produces a dust cloud.

If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing the operations should be wearing flame-retardant clothing, wearing antistatic shoes, and standing on antistatic floor covering or antistatic floor mats.

If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing will not be necessary. However, antistatic footwear, static-dissipative floor covering, or both should be used.

A.14.5.7 See the discussion under A.14.5.4.

A.14.5.7.8 Compacted niobium powder, when heat treated under argon or a vacuum, behaves in a similar fashion to niobium powder. When heat treated, the passivated oxide film present on the surface of each niobium particle comprising the compact diffuses into the center of each particle.

Upon removal from the heat treatment furnace, the passivated oxide film should be re-established through exposure to air. Because the oxidation of niobium generates heat, it is important that the temperature of the compact is below 50°C (122°F) when the compact is exposed to air. This practice prevents the re-oxidation of the compact from proceeding at such a rate that the compact becomes too hot. If the compact becomes too hot, a risk of ignition and fire will exist. Separating the trays of compacts further reduces the risk by providing uniform exposure to air and prevents localized hot spots from developing. It is essential to ensure that all niobium particle surfaces become re-oxidized prior to further processing of the heat-treated niobium compacts.

A.14.7 Section 14.7 applies to operations where niobium or niobium alloys are subjected to processing or finishing operations. The operations specified in Section 14.7 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

A.14.8.1.3.1 Sufficient separation in bulk storage areas should be maintained between the niobium powders and other materials stored in the same area. Storage of niobium powders intermixed with other combustible materials might cause problems in fighting a fire or ignite as a result of burning materials stored in the same area as the niobium. Niobium at elevated temperatures is highly reactive to water and can cause a severe fire or explosion.

A.14.9.3 All welding of niobium should be carried out under an inert atmosphere, such as helium or argon, or under vacuum. An inert gas chamber, commonly known in the industry as a dry welding box, or glove box, is typically used for performing niobium welding operations. Such equipment is often equipped with a mechanical vacuum pump system with inert gas back fillings and purging system to effect evacuation of the chamber and provide a regulated supply of inert gas at or slightly above atmospheric pressure. For further information, the equipment manufacturers or the American Glove Box Society should be consulted.

Cleaning methodologies should consider the hazards of generating airborne dusts and the dangers associated with the use of vacuum cleaners. NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, gives requirements for welding operations.

A.15.1 Figure A.15.1 shows how the user would navigate through this chapter on tantalum.

A.15.1.4.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal that reduces that oxide. The main concern is for iron oxide and fine magnesium particulate, especially powder, and molten magnesium, although there are documented instances of magnesium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to magnesium and iron oxide. There have been recorded incidents where copper oxide and/or lead oxide in contact with magnesium have created the conditions for a thermite reaction. Once initiated via a heat source, a thermite reaction is vigorous and should be treated as a metal fire.

A.15.2.1.5 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.15.2.1.14 In some tantalum-processing operations, process equipment requires cooling water. Under these circumstances, a hazard operations review should be conducted on the site and locations to determine where to feed the water. Water pipes necessary for providing cooling water should be located in such a fashion that they minimize their exposure to areas where it is determined that the risk of a tantalum fire is greatest. It is recognized that tantalum powders can be ignited by exposure to hot surfaces. As such, the use of cooling water in a judicious manner is deemed as a means by which hot surfaces can be reduced or eliminated.

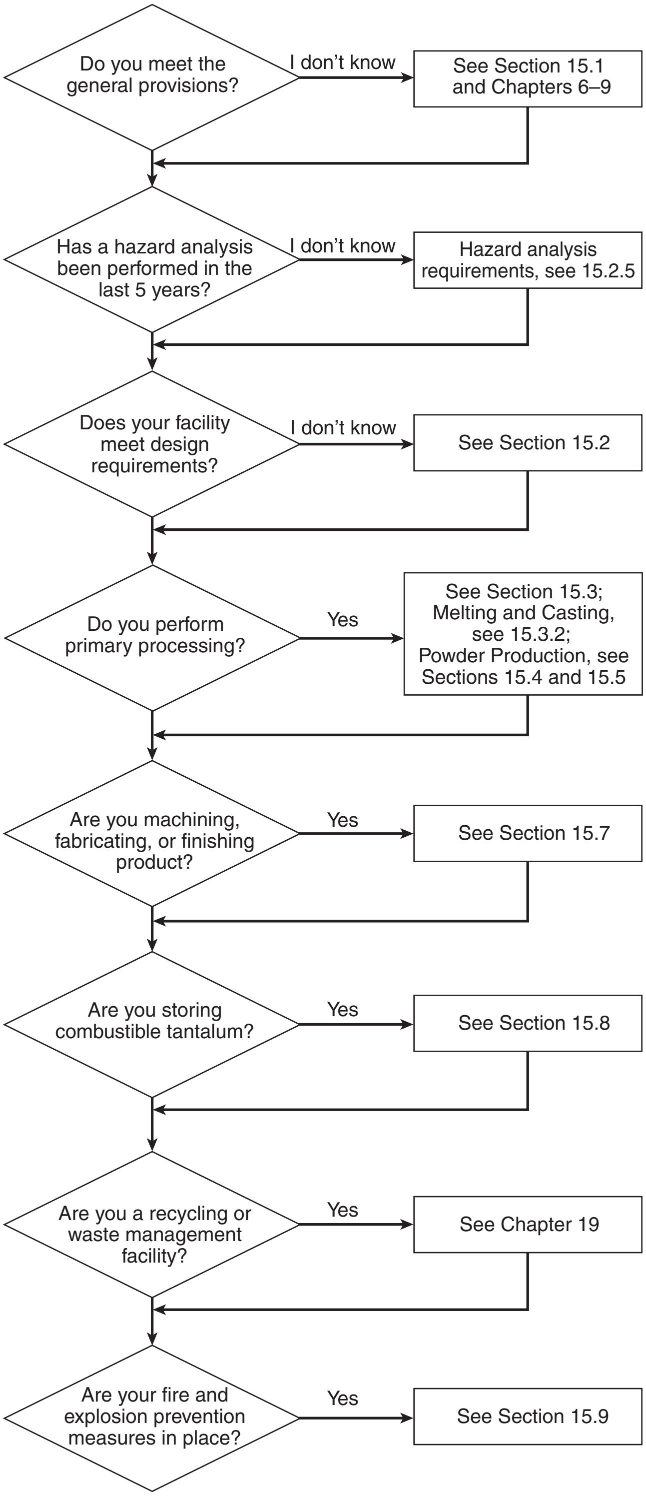


FIGURE A.15.1 Flow Diagram for Tantalum.

A.15.2.1.16.2 The design of deflagration venting should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.15.2.1.16.2.1 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, *Standard on Explosion Protection by Deflagration Venting*.

Deflagration vent closures should be designed such that, once opened, they remain open to prevent failure from the vacuum following the pressure wave.

A.15.2.1.16.2.2 For further information on restraining vent closures, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.15.2.1.18 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.15.2.2.1.1 Because it is almost impossible to extinguish a massive fire in dry aluminum powder, the fire problem can be effectively resolved only by controlling such a fire in the incipient stage. The requirements of 15.2.2 should be followed if the fire is to be controlled quickly. This is especially true with regard to the application of the extinguishing material, because even a minor dust cloud can explode violently.

A properly ringed fire will develop a hard crust of metal oxide that will ultimately exclude enough oxygen to cause self-extinguishment. It is customary practice, after dispensing the extinguishing material, to leave the area, closing all doors leading to the area and sealing them with sand. The area should not be re-entered until combustion has stopped and the material has cooled.

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 aluminum 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 nonsparking metal should be provided at each such receptacle to afford a ready means of laying the material around the perimeter of the fire.

Nearly all vaporizing liquid–fire-extinguishing agents react violently with burning aluminum, 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.15.2.2.1.4 Experience has shown that dry sodium chloride is one of the most effective chemicals for containing fires involving aluminum. Fire-fighting salts should be checked periodically to ensure that they have not become caked from moisture. Another effective chemical is a nonmetallic flux compound consisting of potassium chloride, magnesium chloride, and calcium fluoride. Commercial dry-powder fire extinguishers or agents approved for use on combustible metals are also effective. Covering the fire completely reduces the accessible oxygen supply, thereby slowing the burning rate so that eventual extinguishment is reached.

A.15.2.2.5 Class B extinguishing agents usually will greatly accelerate combustible aluminum dust fires and can cause burning metal to explode.

A.15.2.2.6.1.1 For the automatic sprinkler provisions for storage and use of flammable and combustible liquids, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.15.3.2.1 Because of tantalum's strong affinity for oxygen and its tendency to become contaminated, tantalum is melted under vacuum or inert gas using water-cooled copper crucibles to contain the molten metal. Partial vacuums are maintained by introduction of argon, helium, or mixtures of inert and reactive gases to the melting chamber.

Since the early 1950s, several titanium-melting furnaces have experienced explosions after water inadvertently entered the melting crucibles during the melting operation. Tantalum and titanium both have a very high affinity for oxygen, which is one of the fundamental causes of melting furnace explosions. While there have been no reported tantalum-melting furnace explosions, it is understood that the potential exists for an incident. Investigation of the tantalum incidents has determined that the following three distinct events working together are responsible for melting furnace explosions:

(1) Rapidly increasing pressure created by water making contact with the molten metal. This is the first phase of furnace explosions. The tremendous pressures generated can result in severe damage to the melting chamber and subsequent paths for the introduction of air into the chamber.
(2) Reaction of the water with the molten tantalum liberating hydrogen gas, the volume of which is dependent on the volume of molten metal in the crucible and the amount of water introduced. Generation of the hydrogen gas in itself does not produce a violent reaction or explosion but creates a potentially hazardous condition in the furnace chamber.
(3) Introduction of air as a result of furnace vessel failure or by operation of valves, doors, or other equipment, which can result in an explosive mixture of hydrogen and oxygen. This explosive mixture can be ignited by the residual heat in the melting crucible.

The sequence of the events is thought to be as follows:

(1) Steam explosion
(2) Generation of hydrogen gas
(3) Introduction of air into the chamber
(4) Ignition and explosion of hydrogen–oxygen gas mixture

A steam explosion by itself can do severe damage, as can an explosion of a hydrogen–oxygen gas mixture. The explosion hazard is present in any tantalum-melting furnace that uses water-cooled copper crucibles.

A.15.3.2.1.1 Entrance of water into the furnace chamber is the primary cause of both steam and hydrogen explosions. Features to reduce or eliminate the entrance of water into the furnace chamber should be incorporated into the design of new equipment or modifications to older equipment. Examples are the use of NaK for cooling media, which has hazards of its own to consider. Newly created hazards should be weighed against the hazards potentially eliminated before the changes are incorporated in practice.

A.15.3.2.1.3 The furnace and crucible assembly should be located in a protective bunker that will direct the explosion away from operating personnel in the adjacent areas. Isolation of the furnaces and remote operation remove the operating personnel from the immediate vicinity of the furnace and reduce the risk of severe injury if an explosion occurs.

A.15.3.2.2 The explosion that can occur due to the rapid phase transformation (liquid to gas) of water trapped below molten metal takes place over a time span of 10^{-5} seconds to 10^{-4} seconds. This time span is faster than a condensed phase detonation. The required pressure-relief device would not be effective in relieving the rapid pressure buildup caused by the rapid transformation of water trapped below molten metal. The required device is intended to safely relieve only a much slower buildup of pressure, such as might occur from small incursions of water onto the surface of the molten metal.

A.15.3.2.3 In vacuum arc remelting furnaces, arcing of the electrode to the mold wall is the primary cause of water being introduced into the chamber. To minimize the risk of arcing, the electrode should be straight and of uniform cross-section to maintain the clearance between the electrode and the mold wall. Additionally, use of magnetic fields should be considered, to deflect the arc away from the mold wall.

Use of an electromagnetic field to contain the arc and prevent arcing to the crucible is standard practice in vacuum arc remelting.

A.15.3.2.4.2 Sudden rises in pressure are an indication of the onset of a steam explosion or a hydrogen or oxygen explosion within the furnace. The normal operating range and rates of rise in pressure for the process should be determined as part of the process control function. High-pressure and rate-of-rise-in-pressure interlocks should be installed to shut off the power to the process when they are activated. Continuation of heat to the process will continue the generation of molten tantalum and result in more hydrogen or steam, or both.

A.15.3.2.5 The process operating parameters should be continuously monitored for abnormal conditions. Waterflow, temperature, and pressure on the cooling system are critical for maintaining the correct cooling conditions. Furnace pressure can provide early warning of abnormal conditions in the furnace chamber. Use of data acquisition to monitor the process is the most effective way to oversee the many parameters that could be of interest. Automatic alarms that warn operators of abnormal conditions are also beneficial. Where a parameter is deemed critical or an indicator of an extreme safety hazard, the use of interlocks to terminate the process is the best course of action.

A.15.3.2.11.2 Loss of water supply to the crucible will result in a meltdown of the copper crucible and subsequently to the entry of water into the furnace chamber. If the normal water supply fails, an emergency water supply system should automatically be actuated. Actuation is best achieved with a low–water pressure interlock that actuates the emergency water supply if the water pressure falls below a prescribed level.

A.15.3.2.12.2 The collection of moisture in the mold could cause the tantalum to react, causing a fire or explosion.

A.15.3.2.13 Locating control consoles away from the immediate vicinity of melting furnaces reduces the risk of injury if an explosion occurs. The distance from the furnace should be determined on a case-by-case basis by assessing the potential, magnitude, and expected path of the explosion. The best sources of technical expertise are the furnace manufacturers, which should consider the issue of remote location of control consoles for any new tantalum-melting furnace, or modification of an existing furnace.

A.15.3.2.14.1 Furnace residues produced in a vacuum or inert gas atmosphere are finely divided powders that have not been exposed to an oxidizing atmosphere. Tantalum has a high affinity for oxygen and will oxidize until a sufficiently thick oxide layer has formed. If the thick oxide layer is formed in a controlled manner, it is called passivation. If the thick oxide layer is formed in an uncontrolled manner, it simply burns due to the exothermic nature of oxidation of tantalum.

Condensed furnace residues are, by nature, extremely fine, on the order of submicrons, and hence oxidize more rapidly and generate more heat than powders with larger particle size distributions.

After the furnace has cooled to ambient temperature, the use of passivation cycles, where controlled amounts of air are introduced into the furnace, will render the material stable. An alternative is to burn the material completely while it is contained in the furnace, followed by cooling to ambient temperature. Burning will result in the complete oxidation of the residue and eliminate the potential for further oxidation.

After passivation or burning of the furnace residues is completed, the material should be placed in covered drums and moved to a designated safe storage location.

A.15.4.1.1 The sensitivity of tantalum powder to ignition through contact with hot surfaces or exposure to hot environments, while in an oxygen-containing environment such as air, is directly proportional to the surface area of the tantalum powder. Even low-surface-area tantalum powders are sensitive to exposure in air to hot environments. Historically, it has been determined that tantalum powders should not be exposed to atmospheres containing oxygen at temperatures above 80°C (176°F). Above that temperature, even passivated tantalum powers are shown to continue to oxidize. Intermediate- and high-surface tantalum powders should not be exposed to hot surfaces at 80°C (176°F). Lower temperatures should be employed.

A.15.4.1.4 Care should be exercised in selection of the type of dryer used to dry tantalum powders. Electric resistance–element dryers should not be used due to the risk of tantalum dust particles coming in contact with the heating elements and igniting. If dryers are outfitted with glass windows for viewing of dryer contents, such windows should be covered with metal mesh reinforcement or external shielding to prevent the possibility of glass projectiles if a tantalum dust cloud explodes. Dryers include tray, drum, rotary, fluidized-bed, pneumatic, spray, and vacuum types.

A.15.4.1.4.8 Dryer control systems are critical components that provide safety during drying operations. The reliability of microprocessor controllers should be checked and inspected on a regular basis (such as daily, weekly). Temperature overshoots can result in dangerous conditions, which might allow dryer chamber temperatures to exceed 80°C (176°F). The reliability of thermocouples and fan controls should also be inspected on a regular basis to ensure correct and safe operation.

A.15.4.1.4.10 When tantalum powder is dried in atmospheres containing oxygen, it is recommended that the dryer be outfitted with a means to allow the introduction of an inerting agent. Because tantalum powder undergoes, under certain conditions, a highly exothermic reaction with nitrogen, nitrogen is not an appropriate inerting agent. The inerting agent of choice is argon or helium. Because of dryer design and configuration, it is sometimes difficult and awkward to use other appropriate extinguishing materials in the event of a tantalum dryer fire. Historically, the use of argon gas in extinguishing a tantalum fire has proven to be very effective.

A.15.4.2.2 The quantity of tantalum powders stored in manufacturing operations and areas should be limited to that needed to continue the operation or process.

A.15.4.2.8 Refer to discussion under A.15.4.1.1.

A.15.4.2.9.1 A means to determine protection requirements should be based on a risk evaluation, with consideration given to the size of the equipment, consequences of fire or explosion, combustible properties and ignition sensitivity of the material, combustible concentration, and recognized potential ignition sources. See AIChE, "Guidelines for Hazard Evaluation Procedures."

The following items are areas of concern during the design and installation of process equipment:

(1) Elimination of friction by use of detectors for slipping belts, temperature supervision of moving or impacted surfaces, and so forth
(2) Pressure resistance or maximum pressure containment capability and pressure-relieving capabilities of the machinery or process equipment and the building or room
(3) Proper classification of electrical equipment for the area and conditions
(4) Proper alignment and mounting to minimize or eliminate vibration and overheated bearings
(5) Use of electrically conductive belting, low-speed belts, and short center drives as a means of reducing static electricity accumulation
(6) When power is transmitted to apparatus within the processing room by a belt or chain, the belt or chain should be encased in a practically dusttight enclosure, constructed of substantial, noncombustible material that should be maintained under positive air pressure. Where power is transmitted by means of shafts, the shafts should pass through close-fitting shaft holes in walls or partitions.

A.15.4.2.9.2(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. For deflagration relief venting through ducts, consideration should be given to the reduction in deflagration venting efficiency caused by the ducts. The length of the relief duct should be restricted to not more than 6 m (20 ft).

A.15.4.2.9.2(5) This method is limited in its effectiveness due to the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A.15.4.2.10 The use of inert gas for all machinery is highly recommended. All typical operations encountered in the processing of tantalum powder produce ignition sources (mechanical friction, impact sparks, hot surfaces, and potentially electrostatic discharge). As such, the primary basis of safety should be the exclusion of oxygen from the atmosphere under which tantalum powder is processed.

A.15.4.2.11.1 Where personnel are working on suitable antistatic or conductive flooring, they should be wearing appropriate footwear. Footwear having resistance in the range of 1×10^6 ohms to 1×10^8 ohms is considered to be antistatic. Generally, it is recommended that personnel limit the conductivity of their footwear to the range of 5×10^4 ohms to 1×10^8 ohms. This range accomplishes grounding of static discharge from the operator but reduces the potential risk of electrocution. All personnel should be electrically grounded when they are working in an environment containing a material possessing an MIE of 100 mJ or less.

A.15.4.2.11.4 Unauthorized personnel should not be permitted in powder-handling areas. Identifying authorized personnel is a decision made by individual companies. Authorized personnel are persons experienced and knowledgeable in hazards associated with tantalum powders. The intent of the requirement is to prevent persons who are not familiar with the hazards associated with tantalum powders from wandering through a production area. This requirement does not preclude such a person from being escorted by authorized personnel.

A.15.5.1.1 Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary, depending on the type of combustible dust and processing methods used.

A.15.5.1.3 Static-dissipative flooring is often employed in tantalum manufacturing and processing plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available methods. Careful examination of the details of this standard will disclose the logic of the use of conductive flooring materials.

The surface of a static-dissipative floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous static electric charges. The maximum resistance of a static-dissipative floor is usually less than 10^6 ohms, as measured between two electrodes placed 0.9 m (3 ft) apart at any points on the floor. The minimum resistance is usually greater than 2.5×10^4 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value provides protection for personnel against electric shocks. Resistance values should be checked at regular intervals, usually once each month.

Refer to *NFPA 70, National Electrical Code*, for equipment and procedures that are acceptable practice for testing for minimum and maximum resistance. Measurements should be made at five or more locations in each room, and the results can be averaged.

For compliance with the maximum resistance limit, the average of all measurements should be less than 10^6 ohms.

For compliance with the minimum resistance limit, one individual measurement should be less than 10^5 ohms, and the average of not less than five measurements should be greater than 2.5×10^4 ohms.

Where resistance to ground is measured, two measurements are customarily made at each location, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to grounds at that location. Measurements are customarily taken with the electrode or electrodes more than

0.9 m (3 ft) from any ground connection or grounded object resting on the floor. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about 5 minutes can be considered the measured value.

A.15.5.1.4 Personnel handling tantalum powder in a procedure that causes the generation of tantalum dust should wear flame-resistant or flame-retardant clothing.

Flame-resistant clothing does not ignite, because the fibers themselves do not support combustion. Flame-retardant clothing consists of a base material, such as cotton, that is treated with a topical chemical additive to make the fabric resist ignition and to make it self-extinguishing. When a flame touches the clothing, the coating initiates a series of chemical reactions, creating gases to extinguish the flame.

The difference between flame-resistant and flame-retardant clothing is the permanency of the flame resistance. With flame-resistant fibers, the properties are permanent; with flame-retardant fibers, the properties can be laundered out unless specific procedures are followed.

Either fiber will allow a few seconds for the employee to react and escape. Pure cotton and wool, while they are considered flame retardant, are not appropriate for protection from tantalum fires, because either will allow the accumulation of tantalum dust within the fiber structure.

A.15.5.1.5 The following are considered spark resistant and appropriate for use with tantalum:

(1) Beryllium-copper
(2) Brass
(3) Phosphorous bronze

Aluminum should not be used because of the potential for thermite sparks. Thermite sparks can occur with aluminum, magnesium, tantalum, or titanium or their alloys in the presence of oxygen carriers such as iron or lead oxide. Thermite sparks are highly incendive (and energetic) sparks that are white hot.

A.15.5.3.1 In the manufacture of product from tantalum powder, it might be necessary to mix the tantalum powder with other additives or to pour the tantalum powder from one container to another. Both of these operations tend to produce tantalum dust clouds. A hazards analysis should be done on any operation that produces a dust cloud.

If the dust cloud causes any dust to accumulate on surrounding surfaces, personnel performing these operations should wear flame-retardant clothing, wear antistatic shoes, and stand on antistatic floor covering or antistatic floor mats.

If the ventilation or exhaust system is sufficient to prevent dust accumulation in the operator's work area, flame-retardant clothing will not be necessary. However, antistatic footwear, static-dissipative floor covering, or both should be used.

A.15.5.4.1 See the discussion under A.15.4.1.1.

A.15.5.6 See A.15.5.3.1.

A.15.5.8 Compacted tantalum powder, when heat treated under argon or vacuum, behaves in a similar fashion to tantalum powder. When heat treated, the passive oxide film present on the surface of each tantalum particle making up the compact diffuses into the center of each particle.

Upon removal from the heat treatment furnace, the passive oxide film needs to be re-established through exposure to air. Because the oxidation of tantalum generates heat, it is important that the temperature of the compact is below 50°C (122°F) when the compact is exposed to air. This practice prevents the reoxidation of the compact from proceeding at such a rate that the compact becomes too hot. If the compact becomes too hot, a risk of ignition and fire exists. Separating the trays of compacts further reduces the risk by providing uniform exposure to air and prevents localized hot spots from developing. It is essential to ensure that all tantalum particle surfaces become reoxidized prior to further processing of the heat-treated tantalum compacts.

A.15.5.8.1 Tantalum compacts after furnacing might also require passivation.

A.15.7 Section 15.7 applies to operations where tantalum or tantalum alloys are subjected to processing or finishing operations. The operations specified in Section 15.7 can include, but are not limited to, grinding, buffing, polishing, sawing, and machining of solids. Media blasting operations include, but are not limited to, abrading, etching, applying an anchor pattern, wheel blast, centrifugal wheel blast, sand blast, grit blast, air blast, airless blast, siphon blast, suction blast, abrasive shot blast, peening, and shot peening of solids.

The same basic prevention measures apply to both tantalum fires and explosions in mill operations. The prevention measures are good housekeeping, elimination of ignition sources, isolation of dust-producing operations and subdivision of large operations, and education of employees regarding hazards.

The basic protection measure against fire hazard is the installation of fixed automatic protection equipment. An important consideration is the ability of the fire protection system to function after an explosion. Suppression systems detect the explosion, suppress it, and extinguish it before dangerous pressures are developed. The pressure wave of an explosion travels at 33.5 m/sec (110 ft/sec), which puts it well ahead of the flame front, which travels at 1.2 m/sec to 1.8 m/s (4 ft/sec to 6 ft/sec). The equipment for suppression consists of the pressure detector, control unit, and appropriate extinguishing agent. The suppressant should block inlets and outlets as well as flood the vessel.

Inerting is the preferred approach for protecting against fire and explosion, because it does not allow ignition to occur. Inerting consists of lowering the oxygen concentration below the point where it can support an ignition. A successful inerting system requires a good method of control to insert the inerting gas into the process, as well as a continuous oxygen analyzer to monitor and shut down the system.

Mill operations processes are a source for the accumulation of tantalum fines, saw chips, dust, and oily metallic scrap and residue. Ignition sources can be electrical, thermal, or mechanical, or static electricity can be the source.

The control of ignition sources is paramount in maintaining a fire-free environment. The following measures provide guidance for controlling ignition sources:

(1) Open flames and smoking should be prohibited.
(2) Cutting and welding in the vicinity of fines, dust, and flammable lubricants should be prohibited.
(3) Electrical equipment, wiring, and lighting in the area should be explosion proof, conforming to National Electrical Manufacturers Association (NEMA) rating class II, Group E, as defined in *Guide for Classification of All Types of Insulated Wire and Cable.*

(4) Blowers and exhaust fans should be suitable for the application. Maintenance should be provided to ensure clearance between the blades and casing.
(5) All equipment should be grounded and bonded to prevent accumulation of static electricity. Electrical grounding of all equipment and containers should be thorough. Static cannot be grounded through an oil or grease film in bearings; therefore, it is necessary to provide wire jumpers around lubricating films.
(6) Sparks caused by metal striking metal should be eliminated.
(7) All sources of mechanical friction should be minimized.
(8) Magnetic separators or screens should be provided to prevent foreign objects from entering grinders, pulverizers, crushers, or other milling equipment.
(9) Nonsparking types of tools should be utilized. Friction caused by hammering, sliding, or rubbing should be avoided.
(10) Individual dust collection systems should be provided for each piece of equipment as much as practical.
(11) Dust-handling equipment should be located adjacent to exterior building walls. Locations in basements should be avoided.

A.15.7.1 All welding of tantalum should be carried out under an inert atmosphere, such as helium or argon, or under vacuum. An inert gas chamber, commonly known in the industry as a dry welding box, or glove box, typically is used for performing tantalum-welding operations. Such equipment is often equipped with a mechanical vacuum pump system with an inert-gas backfilling and purging system to effect evacuation of the chamber and provide a regulated supply of inert gas at or slightly above atmospheric pressure. For further information, the equipment manufacturers or the American Glove Box Society should be consulted.

Cleaning methodologies should consider the hazards of generating airborne dusts and the dangers associated with the use of vacuum cleaners.

A.15.7.4.2.1 The principal fire hazard is the ease of ignition of finely divided combustible material with subsequent ignition of the less easily ignited particles.

A.15.7.4.4 Improperly designed or dulled tools can produce high temperature at the tool-metal interface, causing ignition of the turnings, if an adequate coolant flow is not used.

A.15.7.4.5 Only mill lubricants with high flash points should be used in rolling and forging operations. All liquids, including lubricants that come into direct contact with the processed metal, pose a fire potential any time the metal heats up to high temperatures in a mill environment in excess of the flash point of the lubricants.

A.15.7.4.8 Petroleum oils in any form are susceptible to relatively low ignition temperatures from any source in a mill environment. Practices that prevent ignition should be followed.

A.15.7.5.1.3 Explosion venting is especially important for combustible tantalum 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, *Standard on Explosion Protection by Deflagration Venting*. Dust collectors, when provided by manufacturers, seldom have properly sized venting to handle a combustible metal dust explosion.

The cyclone dust collector should be of conductive metal of suitable construction for the service intended and solid welded with smooth internal seams. The equipment should be provided with a sparkproof air lock on the hopper discharge and connected to a covered material receiver. Exhaust fans used in conjunction with this equipment should be installed on the clean-air side of the system and be of sparkproof construction. Motors and controls of any type associated with the process airstream should be located outside the process airstream. All associated equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

In processes where the component part consists of a variety of materials and it is not possible to segregate the combustible metal component during the finishing process, it should be noted that this condition presents an additional hazard in the process ventilation equipment. Daily inspection, cleaning, and general maintenance of the system should be performed to minimize exposure to inherent risks when finishing procedures are performed on these types of parts.

A.15.7.5.2.3 If inert gas is used, the inert gas should be argon or helium. Nitrogen gas should not be used.

A.15.8.1.3.1 Sufficient separation in bulk storage areas should be maintained between the tantalum powders and other materials stored in the same area. Storage of tantalum powders intermixed with other combustible materials might cause problems in fighting a fire or ignite as a result of burning materials stored in the same area as the tantalum. Tantalum at elevated temperatures is highly reactive to water and can cause a severe fire or explosion. *(See Annex B for additional information.)*

A.16.1 Figure A.16.1 shows how the user would navigate through this chapter on titanium.

A.16.1.4.1 Thermite reactions are extremely exothermic [e.g., temperatures in excess of 2204°C (4000°F)]. A thermite reaction typically occurs between one metal oxide and another metal, which reduces that oxide. The main concern is for iron oxide and fine titanium particulate, especially powder, although there are documented instances of titanium grinding fines initiating such a reaction. The thermite reaction is not necessarily limited to titanium and iron oxide, and even thin metal sheet can be ignited. There have been recorded incidents where chrome oxide, copper oxide, and/or lead oxide in contact with titanium have created the conditions for a thermite reaction.

A.16.1.4.2 For practical consideration, a eutectic reaction involving titanium is one involving another metal, usually iron or nickel base, where the mixture melts at a lower temperature than either of the individual metals.

For this reaction to take place, heat, pressure, and intimate contact are required; the reaction would be accelerated via finely divided particulate of either material.

The hazard is of the unexpected occurrence of flowing, molten, highly reactive metal. The molten mixture should be treated as a metal fire and contained with refractory material.

A.16.1.5 It is essential to have thorough written documentation, as the slightest changes to procedures, processes, and/or equipment, including those from suppliers, can have a dramatic impact on the overall hazard analysis.

Change includes something as benign as process materials replacements-in-kind from different manufacturer, same manufacturer using new methods to produce the product, or changes in formulation. These changes from suppliers can impact the characteristics of the processes and/or materials.