NFPA® 484

Standard for Combustible Metals

2009 Edition

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NFPA® 484

Standard for

Combustible Metals

2009 Edition

This edition of NFPA 484, *Standard for Combustible Metals,* was prepared by the Technical Committee on Combustible Metals and Metal Dusts. It was issued by the Standards Council on July 24, 2008, with an effective date of October 10, 2008, and supersedes all previous editions.

This edition of NFPA 484 was approved as an American National Standard on October 10, 2008.

Origin and Development of NFPA 484

NFPA 484, *Standard for Combustible Metals, Metal Powders, and Metal Dusts*, 2002 edition, 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*; 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 gave safety requirements for all combustible metals, including processing, storage, handling, dust collection, housekeeping, and fire protection.

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

The 2009 edition of NFPA 484 contains 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.

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

Changes other than editorial are indicated by a vertical rule beside the paragraph, table, or figure in which the change occurred. These rules are included as an aid to the user in identifying changes from the previous edition. Where one or more complete paragraphs have been deleted, the deletion is indicated by a bullet (•) between the paragraphs that remain.

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 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, that exhibit combustion characteristics of aluminum, alkali metals, magnesium, tantalum, titanium, or zirconium shall be subject to the requirements of the metal whose combustion characteristics they most closely match.

1.1.4 Metals and metal alloy parts and those materials, including scrap, that do not exhibit combustion characteristics of alkali metals, aluminum, magnesium, niobium, tantalum, titanium, or zirconium are subject to the requirements of Chapter 10.

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

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

1.1.7 This standard shall apply to laboratories that handle, use, or store more than ½ lb of alkali metals or 2 lb aggregate of other combustible metals, excluding alkali metals.

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

1.1.9* If the quantity of a combustible metal listed in Table 1.1.9 is exceeded in an occupancy, the requirements of NFPA 484 shall apply.

Table 1.1.9 Applicability Thresholds by Occupancy

Occupancy Class (as defined in *NFPA 5000*, 2009 edition)	Threshold Quantity (kg)	Threshold Quantity (lb)
Assembly	0.4535	1
Educational	0.907	2
Day care	Not permitted	
Health care	0.907	2
Ambulatory health care	0.907	2
Detention and correctional	Not permitted	
Residential	0.907	2
Residential board and care	Not permitted	
Mercantile	0	
Business	4.535	10 for storage; 0 for use and handling
Industrial	2.2675	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 document shall be considered necessary to provide a reasonable level of protection from loss of life and property from fire and explosion.

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

1.3.3 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 Chapter 13 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,* 2009 edition.

NFPA 10, *Standard for Portable Fire Extinguishers,* 2007 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 2007 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 2008 edition.

NFPA 33, *Standard for Spray Application Using Flammable or Combustible Materials,* 2007 edition.

NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids,* 2007 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work,* 2009 edition.

NFPA 54, *National Fuel Gas Code,* 2009 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2008 edition.

NFPA 70®, National Electrical Code®, 2008 edition.

NFPA 80, *Standard for Fire Doors and Other Opening Protectives,* 2007 edition.

NFPA 86, *Standard for Ovens and Furnaces,* 2007 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 2004 edition.

NFPA *101®*, *Life Safety Code®,* 2009 edition.

NFPA 220, *Standard on Types of Building Construction,* 2009 edition.

NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls,* 2009 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment,* 2008 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operations,* 2006 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2006 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response,* 2007 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems,* 2008 edition.

NFPA 5000®, Building Construction and Safety Code®, 2009 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 B31.3, *Chemical Plant and Petroleum Refinery Piping,* 1993 edition.

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,* 2004.

ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C,* 1998.

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

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: Model Regulations — Manual of Tests and Criteria, 13th edition.

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

2.4 References for Extracts in Mandatory Sections.

NFPA 68, *Standard on Explosion Protection by Deflagration Venting,* 2007 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 2008 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids,* 2004 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids,* 2006 edition.

NFPA 921, *Guide for Fire and Explosion Investigations,* 2008 edition.

NFPA 5000®, Building Construction and Safety Code®, 2009 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 shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1 Alkali Metals. See 3.3.25.1.

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 3.3.29.3.

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

3.3.5 Combustible Metal. See 3.3.25.2.

3.3.6* Combustible Metal Dust. Any finely divided metal 425 microns (40 mesh) or smaller.

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,** 2007]

3.3.9 Dryer. A piece of processing equipment using temperature or pressure change to reduce the moisture or volatile content of the material being handled. [**654,** 2006]

3.3.10 Duct. Pipes, tubes, or other enclosures used for the purpose of pneumatically conveying materials. [**91,** 2004]

3.3.11 Dust. See Combustible Metal Dust, 3.3.6.

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

3.3.13 Fines.

3.3.13.1 ***Aluminum Fines.*** The fraction of an aluminum powder that is 45 μm (microns) (325 mesh) or smaller in nominal diameter, either as a discrete particle or as agglomerates of discrete particles.

3.3.13.2 ***Magnesium Fines.*** The fraction of a magnesium powder that is 44 μm (microns) (320 mesh) or smaller in nominal diameter, either as a discrete particle or as agglomerates of discrete particles.

3.3.13.3 ***Tantalum Ultra Fines.*** The fraction of a tantalum powder that is 10 μm (microns) or smaller in nominal diameter, either as discrete particles or as agglomerates of discrete particles.

3.3.13.4 ***Titanium or Zirconium Fines.*** The fraction of a titanium or zirconium powder that is 44 μm (microns) (320 mesh) or smaller in nominal diameter, either as a discrete particle or as agglomerates of discrete particles.

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

3.3.15 Fugitive Material. See 3.3.22.1.

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

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

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

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

3.3.20* 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.

3.3.21 Magnesium Ribbon. Magnesium metal that is less than 3.2 mm (⅛ in.) in two dimensions or less than 1.3 mm (1/20 in.) in single dimension is considered a powder.

3.3.22 Material.

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

3.3.22.2* ***Pyrophoric Material.*** A chemical with an autoignition temperature in air at or below 130°F (54.4°C). [***5000***, 2009]

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

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

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

3.3.25 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.

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

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

3.3.26* 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**, 2006]

3.3.27* 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.

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

3.3.28.1 ***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.

3.3.29 Powder. Granules, dusts, fines, ultra fines, and other substances defined according to the specific metal.

3.3.29.1* ***Aluminum Flake Powder.*** See 3.3.29.3.

3.3.29.2 ***Aluminum Granular Powder.*** See 3.3.29.3.

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

3.3.29.4* ***Combustible Metal Powder.*** Combustible particulates that are intentionally produced as the product of a manufacturing process.

3.3.29.5 ***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.

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

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

3.3.31 Pyrophoric Material. See 3.3.22.2.

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

3.3.33 Spark-Resistant Material. See 3.3.22.3.

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

3.3.35 Spontaneous Heating. Process whereby a material increases in temperature without drawing heat from its surroundings. [**921**, 2008]

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

3.3.37 Tantalum Powder. See 3.3.29.5.

3.3.38 Tantalum Ultra Fines. See 3.3.13.3.

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

3.3.40 Titanium Fines. See 3.3.13.4.

3.3.41 Zirconium Fines. See 3.3.13.4.

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

4.1* Overview. The screening test in Section 4.2 or in Section 4.3 shall be conducted to determine if a metal is in combustible or explosive 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 4.1.3 and 4.1.4 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.

4.1.6 Forms of combustible metal dust (CMD) that have been evaluated as noncombustible shall be required to be reevaluated whenever a change in manufacture, processing, handling, or storage conditions creates a modified form that might exhibit the characteristic of combustibility.

4.2 Determination of Combustibility.

4.2.1* 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.

4.2.2 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

4.2.3 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.

4.2.4* If the results of the screening test provide propagation along any length of the powder train beyond the heated zone, the material shall be considered to be in a combustible form.

4.2.5* 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.

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

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

4.3 Determination of Explosibility.

4.3.1* The determination of explosibility of metals, metal powders, metal dusts, and alloys of these materials shall be determined by using the flow chart in Figure 4.3.1.

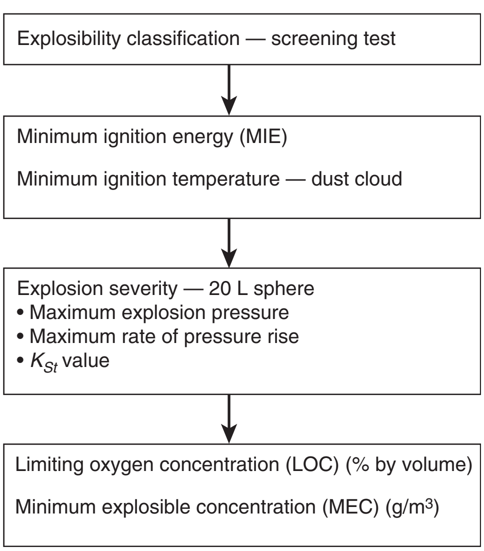


FIGURE 4.3.1 Determination of Explosibility.

4.3.2* The explosibility classification screening test shall serve as the basis to determine whether a metal, metal powder, metal dust, or alloy of these materials is capable of initiating or sustaining an explosion when suspended as a dust cloud.

4.3.3* Test samples for the preliminary 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.

4.3.4* The explosibility classification screening tests shall be conducted using a modified Hartmann apparatus with a constant arc energy in accordance with ASTM E 2019, *Standard Test Method for Minimum Ignition Energy of a Dust Cloud in Air.*

4.4 Risk Evaluation. Where a risk evaluation *(see Annex I)* is required by the AHJ, the following data shall be determined:

(1) Minimum ignition energy (MIE)
(2) Maximum pressure (P_{max})
(3) Pressure rise *(dP/dt)*
(4) Deflagration index (K_{St})
(5) Limiting oxygen concentration (LOC)
(6) Minimum explosible concentration (MEC)
(7) Thermal stability
(8) Electrostatic risk
(9) Water reactivity

Chapter 5 Alkali Metals

5.1* General Precautions.

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

5.1.2* Handling, Processing, and Storage Areas for Alkali Metals.

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

5.1.2.2 NFPA Hazard Identification Markings.

5.1.2.2.1 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.

5.1.2.2.2 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.*

5.1.3* Alkali Metal Fire Residue.

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

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

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

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

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

5.1.3.6 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.

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

5.2* Building Construction.

5.2.1 General.

5.2.1.1 Section 5.2 shall apply to buildings or portions of buildings that are dedicated to the handling, processing, or storage of solid or molten alkali metal.

5.2.1.2 Noncombustible Materials.

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

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

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

5.2.1.4* Roof decks shall be watertight.

5.2.1.5 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*.

5.2.1.6* 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.

5.2.1.7* Floor drains shall not be permitted.

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

5.2.1.8.1 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.

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

5.2.2 Separation from Water.

5.2.2.1* 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.

5.2.2.1.1 Water pipes required for safety operations shall be permitted.

5.2.2.1.2 Piping permitted by 5.2.2.1.1 shall be equipped with an emergency shutoff that is identified and located outside the area.

5.2.2.1.3 Piping permitted by 5.2.2.1.1 shall be constructed of steel.

5.2.2.2 A sprinkler system(s) deemed appropriate per 13.3.3 shall be permitted.

5.2.2.3 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.

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

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

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

5.3 Handling or Processing of Solid or Molten Alkali Metals.

5.3.1 General Precautions.

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

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

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

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

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

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

5.3.1.6* No open flames, electric or gas cutting or welding operations or equipment, grinding, or other spark-producing operations or equipment shall be permitted in any section of the building where alkali metals are present unless approved hot-work procedures are followed by qualified personnel.

5.3.1.7* 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.

5.3.2 Solid Alkali Metal Handling.

5.3.2.1* 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.

5.3.2.2 Moisture Protection.

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

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

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

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

5.3.3 Molten Alkali Metal Handling.

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

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

5.3.3.3 Molten alkali metal piping systems shall be designed in conformance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*.

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

5.3.3.4 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.

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

5.3.3.6 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.

5.4 Storage of Solid or Molten Alkali Metals.

5.4.1 General Precautions.

5.4.1.1* Alkali metals shall be permitted to be stored in shipping containers that meet the requirements of UN guidelines 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.

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

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

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

5.4.2 Solid Alkali Metals Storage.

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

5.4.2.2 There shall be no basement or depression below the alkali metals storage area into which water or molten metal shall be allowed to flow or fall during a fire.

5.4.2.3 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.

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

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

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

5.4.2.4.3 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.

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

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

5.4.3 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.

5.5* Fire Protection. Fire protection shall be established in accordance with Chapter 13.

5.6 Personal Protective Equipment for Molten Alkali Metal– and Solid Alkali Metal–Handling Operations.

5.6.1* Personal Protective Equipment for Solid Alkali Metals Handling.

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

5.6.1.2 Personnel shall wear gloves while handling solid alkali metals.

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

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

5.6.2* Personal Protective Equipment for Handling Molten Alkali Metals.

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

5.6.2.2 While handling molten alkali metals, personnel shall wear safety glasses and face shields.

5.6.2.3 Gloves shall be worn and shall be loose fitting, easily removable, and compatible with the hazards of molten alkali metals.

5.6.2.4 All clothing shall be loose fitting, easily removable, flame resistant, and compatible with the hazards of molten alkali metals.

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

5.6.2.6 Protective footwear shall be appropriate for the hazards of molten alkali metals.

Chapter 6 Aluminum

6.1 Aluminum Powder Production Plants.

6.1.1 Location.

6.1.1.1 Aluminum powder production plants shall be located on a site large enough so 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.

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

6.1.2 Building Construction.

6.1.2.1 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.

6.1.2.2 The buildings specified in 6.1.2.1 shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

6.1.2.3 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.

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

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

6.1.2.6 The requirements of 6.1.2.5 shall also apply to elevated platforms, balconies, floors, and gratings.

6.1.2.7 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.

6.1.2.8 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.

6.1.2.9 Roof decks and basements shall be watertight.

6.1.2.10* Explosion venting shall be provided for buildings where aluminum powder is processed.

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

6.1.3 Door and Window Construction.

6.1.3.1 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.*

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

6.1.4 Enclosed Passageways.

6.1.4.1* 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.

6.1.4.2 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.*

6.1.5 Grounding and Lightning Protection.

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

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

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

6.1.6 Electrical Power and Control.

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

6.1.6.2* In local areas of a plant where a hazardous quantity of 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.*

6.1.6.2.1 Offices and similar areas within the aluminum powder–manufacturing building that are segregated and reasonably free from dust shall not be classified.

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

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

6.1.6.4 All manufacturing buildings shall be provided with emergency lighting systems in accordance with Section 7.9 of NFPA *101*, *Life Safety Code.*

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

6.1.6.6 Electrical equipment shall be inspected and cleaned at least once each year or more frequently if conditions warrant.

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

6.1.7 Heating and Cooling of Aluminum Powder–Production Buildings.

6.1.7.1 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.

6.1.7.2 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.

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

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

6.1.7.5 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.

6.1.7.6 The requirements of 6.1.7.1 through 6.1.7.5 shall not apply to areas where aluminum metal is melted.

6.1.8 Machinery and Operations.

6.1.8.1 General Precautions. The precautions of 6.1.8.1.1 through 6.1.8.1.3 shall apply to new and existing facilities where aluminum powder is produced or handled.

6.1.8.1.1 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; or other energy sources.

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

6.1.8.1.3* Frictional heating shall be minimized by the use of lubrication, inspection programs, and maintenance programs and techniques set forth by the equipment manufacturer's recommendations.

6.1.8.2 Requirements for Machinery.

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

6.1.8.2.2 All machinery and equipment shall be installed in accordance with *NFPA 70, National Electrical Code*.

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

6.1.8.2.4 Bearings.

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

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

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

6.1.8.2.6 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.

6.1.8.3 Start-Up 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 into operation.

6.1.9 Handling and Conveying of Aluminum Powder.

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

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

6.1.9.3 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.

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

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

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

6.1.9.7 Portable Containers.

6.1.9.7.1 Transport of aluminum powders shall be done in covered conductive containers as described in 6.1.9.4.

6.1.9.7.2 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 6.1.6.2.

6.1.9.8 Ductwork for Pneumatic Conveying Systems. Conveyor ducts shall be fabricated of nonferrous spark-resistant metal or spark-resistant stainless steel.

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

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

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

6.1.9.8.4 A minimum conveying velocity of 1372 m/min (4500 ft/min) 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.

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

6.1.9.8.6* Deflagration venting such as rupture diaphragms shall be provided on ductwork.

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

6.1.9.8.6.2 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.

6.1.9.8.7 Whenever damage to other property or injury to personnel can result from the rupture of the ductwork, or where deflagration relief vents cannot provide sufficient pressure relief, the ductwork shall be designed to withstand a suddenly applied gauge pressure of at least 690 kPa (100 psi).

6.1.9.8.8 If a portion of the ductwork is so located that no damage to property or injury to personnel will result from its bursting, that portion shall be permitted to be of lightweight construction so as to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

6.1.9.9 Conveying Using an Inert Medium.

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

6.1.9.9.2* The inert gas used shall be based on such gases as argon, carbon dioxide, helium, nitrogen, or flue gas and shall have a limiting oxygen concentration (LOC) determined by test to be appropriate to the inert gas except that, where the aluminum powder is never exposed to air, the oxygen content shall be permitted to be zero.

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

6.1.9.9.4 The inert gas stream shall be continuously monitored for oxygen content and shall be arranged to sound an alarm if the oxygen content is not within the prescribed range.

6.1.9.9.5 A minimum conveying velocity of 1372 m/min (4500 ft/min) 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.

6.1.9.9.6 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.

6.1.9.10 Fan and Blower Construction and Arrangement.

6.1.9.10.1* Blades and housings of fans used to move air or inert gas in conveying ducts shall be constructed of conductive, nonsparking metal such as bronze, nonmagnetic stainless steel, or aluminum.

6.1.9.10.2 The design of the fan or blower shall not allow the transported aluminum powder to pass through the fan before entering the final collector, unless the aluminum powder–conveying system is inerted.

6.1.9.10.3 Personnel shall not be permitted within 15 m (50 ft) of the fan or blower while it is operating, except as provided in 6.1.9.10.3.2 and 7.5.4.2.3.

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

6.1.9.10.3.2 If personnel approach the fan or blower while it is operating, such as for a pressure test, 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 aluminum powder cut off.

• **6.1.9.10.4*** 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.

6.1.9.10.5* Fans or blowers shall be equipped with ball or roller bearings. Bearings shall be equipped with temperature-indicating devices and shall be arranged to sound an alarm in case of overheating.

6.1.9.10.6 Fans or blowers shall be electrically interlocked with powder-producing machinery so that the machines are shut down if the fan stops.

6.1.10 Powder Collection.

6.1.10.1* Collectors.

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

6.1.10.1.2* The area around the collector shall be posted with a sign that reads as follows:

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

6.1.10.1.3 Collectors shall be constructed of metal to allow dissipation of static electricity.

6.1.10.1.4 Ductwork shall comply with the provisions of 6.1.9.8.

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

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

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

6.1.10.1.7.1 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.

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

6.1.10.1.8 Repairs.

6.1.10.1.8.1 Where repairs on dry-dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed. *(See 6.4.2.)*

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

6.1.10.2 High-Temperature Warning.

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

6.1.10.2.2 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 32°C (90°F) below the ignition temperature of the powder cloud, whichever is lower.

6.1.10.2.3 The devices specified in 6.1.10.2.2 shall give audible and visual alarms at normally attended locations.

6.1.10.3* Collector Filter Medium. Collector filter medium made from synthetic fabrics that accumulate static electric charges shall not be used.

6.1.11 Storage of Aluminum Powder. When aluminum powder is stored in sealed containers, the procedures of 6.1.11.1 through 6.1.11.7 shall apply.

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

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

6.1.11.3 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.

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

6.1.11.5 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.

6.1.11.5.1 Stacked storage shall be arranged to ensure stability.

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

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

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

6.2 Aluminum Powder Handling and Use.

6.2.1 Scope. The provisions of Section 6.2 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.

6.2.2 Storage. Dry aluminum powder and aluminum paste shall be stored in accordance with the provisions of 6.1.11.

6.2.3* Handling. The requirements of Section 6.2 shall apply to both regular and "nondusting" grades of aluminum powder, as well as aluminum paste.

6.2.3.1 Where aluminum powder or paste is used or handled, good housekeeping practices shall be maintained.

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

6.2.3.3 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.

6.2.3.4 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 6.1.6.2.

6.2.4 Machinery and Operations.

6.2.4.1* Wet Milling of Aluminum Powder. The requirements of 6.2.4.1.1 through 6.2.4.1.6 shall not apply to machining and rolling operations.

6.2.4.1.1* 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.

6.2.4.1.2* 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.

6.2.4.1.3 The dew point of the atmospheres in 6.2.4.1.1 and 6.2.4.1.2 shall be maintained below the point where condensation occurs.

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

6.2.4.1.5* 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.

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

6.2.4.2 Electrical Equipment.

6.2.4.2.1 All electrical wiring and equipment shall conform to the provisions of *NFPA 70, National Electrical Code*.

6.2.4.2.2* All components of collector systems shall be electrically bonded and grounded.

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

6.2.4.2.4* 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*.

6.2.4.3 Plasma Spray Operations.

6.2.4.3.1 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 medium in the collector.

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

6.2.4.4 In local areas of a plant where a hazardous quantity of 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*.

6.2.5* Transfer Operations. 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.

6.2.6 Prevention of Fugitive Dust Accumulations. See Section 6.4.

6.3 Processing and Finishing Operations.

6.3.1* Scope.

6.3.1.1 Section 6.3 shall apply to operations where aluminum or aluminum alloys are subjected to processing or finishing operations.

6.3.1.2 The operations specified in 6.3.1.1 shall include, but shall not be limited to, grinding, buffing, polishing, sawing, and machining of solids.

6.3.2 Dust-Producing Operations.

6.3.2.1* Machines that produce fine particles of aluminum 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.

6.3.2.2 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.

6.3.2.3* 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.

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

6.3.2.5* Dry-type dust collectors shall be located outside of buildings.

6.3.2.5.1* Individual machines with portable dust collection capability 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 6.3.2.5.1(A) through 6.3.2.5.1(D).

(A) The operation of portable dust collection devices shall be subject to a hazards analysis to ensure that the risk to personnel and operations from flash fire and shrapnel is minimized.

(B) Personnel protective clothing shall comply with 6.6.2.

(C) The collector shall be designed to dissipate static electricity.

(D) Collector retention capacity shall be limited to 0.45 kg (1 lb).

6.3.2.5.2* Dry-type collectors shall be provided with barriers or other means for protection of personnel.

6.3.2.5.3* The area around the collector shall be posted with a sign that reads as follows:

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

6.3.2.6* Dust collection systems shall be dedicated to the collection of aluminum or aluminum alloy dust only.

6.3.2.6.1 Grinders, buffers, and associated equipment with dust collectors utilized for processing aluminum shall be provided with a placard that reads as follows:

> **WARNING:** Aluminum Metal Only — Fire or Explosion Can Result with Other Metals.

6.3.2.6.2 If the combustible aluminum dust collection system is to be used for other materials, the system shall be disassembled and thoroughly cleaned of all incompatible materials prior to and after its use.

6.3.3 Dust Collection Ducts and Ductwork.

6.3.3.1 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.*

6.3.3.2 Ducts shall be designed to maintain a velocity of not less than 1364 m/min (4500 ft/min) 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).

6.3.3.3* Ducts shall be designed to handle a volumetric flow rate that maintains dust loading safely below the MEC.

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

6.3.3.5 Duct Construction.

6.3.3.5.1 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.

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

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

6.3.3.5.4 Additional branch ducts shall not be added to an existing system without redesign of the system.

6.3.3.5.5 Branch ducts shall not be disconnected nor shall unused portions of the system be blanked off without means being provided to maintain required airflow.

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

6.3.4 Wet-Type Dust Collectors.

6.3.4.1* The exhaust vent shall terminate outside of the building and shall be securely fastened.

6.3.4.1.1 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.

6.3.4.1.2 The cleaned 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 safety 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. *(See 6.5.2.1.)*

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

6.3.4.3 Location of Dust Collector.

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

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

6.3.4.4* 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 additional dry filter medium either downstream or combined with a wet collector shall not be permitted.

6.3.4.5* Collector Sludge.

6.3.4.5.1 Sludge shall be removed from the collector on a regular schedule to ensure proper and safe operation of the equipment.

6.3.4.5.2 Sludge shall be disposed of in accordance with the requirements of 6.3.4.8.

6.3.4.6 Collector Sump Venting.

6.3.4.6.1* The sump of water wet-type dust collectors shall be ventilated at all times.

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

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

6.3.4.7 Power Supply.

6.3.4.7.1 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.

6.3.4.7.2 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent the starting of its motor drive until the collector is in complete operation.

6.3.4.8 Disposal of Sludge from Water Wet-Type Dust Collectors.

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

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

6.3.4.8.3 Sludge shall be permitted to be mixed with inert materials in a ratio of at least 5 parts inert material to 1 part sludge and then shall be recycled or discarded in accordance with local, state, and federal requirements.

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

6.3.5 Dry-Type Dust Collectors.

6.3.5.1 Electrostatic collectors shall not be used.

6.3.5.2* Dust-collecting filter medium shall be designed to be conductive so as to dissipate static electric charges.

6.3.5.3 Dry-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.

6.3.5.4 The accumulation or condensation of water at any point in the dry-dust collection system shall be prevented.

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

6.3.5.5.1 Extreme care shall be taken in removing dust from the collectors, to avoid creating dust clouds.

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

6.3.5.5.3 Waste material shall be mixed with an inert material in a volume ratio of five parts inert material to one part metal dust and shall be recycled or disposed of in accordance with local, state, and federal regulations.

6.3.5.6* Dry collectors used for combustible aluminum dust shall be provided with deflagration vents. 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.

6.3.5.7 Where repairs on dry-dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed *(see 6.4.2)*. Ductwork leading into the collector shall be disconnected and blanked off before repair work is permitted to be started.

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

6.3.5.9 The dust collector shall be arranged so that contact between dust particles and parts moving at high speeds is prevented. The blower for drawing the dust-laden air into the collector shall be located on the clean air side of the collector.

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

6.3.7 Machining and Sawing Operations.

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

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

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

6.3.7.4 Coolant.

6.3.7.4.1 Nonflammable coolants shall be used for wet grinding, cutting, or sawing operations.

6.3.7.4.2 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.

6.3.8 Electrical Equipment.

6.3.8.1 All electrical wiring and equipment shall conform to the provisions of *NFPA 70, National Electrical Code*.

6.3.8.2* Bonding and Grounding.

6.3.8.2.1 All components of dust collection systems shall be electrically bonded and grounded.

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

6.4 Housekeeping.

6.4.1 Scope. Section 6.4 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

6.4.2 Cleanup Procedures for Fugitive Dust Accumulations.

6.4.2.1* Fugitive dust shall not be allowed to accumulate.

6.4.2.2 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) Vacuum cleaning systems designed for handling combustible metal powders in accordance with 6.4.3

6.4.2.3 Cleanup of Spilled Aluminum Powder.

6.4.2.3.1 Preliminary cleanup of the bulk of the powder shall be accomplished by using conductive, nonsparking scoops and soft brooms as well as brushes that have natural fiber bristles.

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

6.4.3* Vacuum Cleaning Systems.

6.4.3.1 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.

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

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

6.4.3.4* Portable vacuum cleaners shall be used only if listed or approved for use with combustible aluminum dust.

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

6.4.3.5.1 Assembled components shall be conductive and bonded where necessary.

6.4.3.5.2 Periodic tests for continuity shall be performed.

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

6.4.4 Compressed Air Cleaning Requirements. Compressed air blowdown shall not be permitted, except in certain areas that are otherwise impossible to clean and, where permitted, shall be performed under carefully controlled conditions with all potential ignition sources prohibited in or near the area and with all equipment shut down.

6.4.5 Water Cleaning Requirements. 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 and powder to a safe, remote area is available.

6.4.6 Cleaning Frequency.

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

6.4.6.2 Regular periodic cleaning of buildings and machinery, with all machinery idle and power off, shall be carried out as frequently as conditions warrant.

6.5 Fire Prevention, Protection, and Procedures.

6.5.1* Scope. Section 6.5 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

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

6.5.2.1* 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.

6.5.2.2 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.

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

6.5.2.4* The dry extinguishing agent shall be carefully applied with a nonsparking metal scoop or shovel or applied from a listed Class D fire extinguisher equipped with a low-velocity nozzle.

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

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

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

6.5.2.6.2 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."

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

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

(B) Halogenated extinguishing agents shall not be used.

6.5.3* Solvent-Wetted Powders.

6.5.3.1 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.

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

6.5.3.3 Carbon Dioxide Use.

6.5.3.3.1* 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.

6.5.3.3.2 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.

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

6.5.3.4 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.

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

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

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

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

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

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

6.5.4 Automatic Sprinkler Protection.

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

6.5.4.1.1* 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.

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

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

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

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

6.5.5 Fire-Fighting Organization.

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

6.5.5.1.1 All other personnel shall be evacuated from the area.

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

6.5.5.2 Fire-fighting personnel shall be given regular and consistent training in the extinguishment of test fires set in a safe location away from manufacturing buildings, including all possible contingencies.

6.5.5.3* If professional or volunteer fire fighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by the on-site ranking officer of the trained plant fire fighters.

6.5.6* 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.

6.5.7 Control of Ignition Sources.

6.5.7.1 No smoking, open flames, electric or gas cutting or welding equipment, or spark-producing operations shall be permitted in the areas where wetted sludge is produced or handled, including the disposal area.

6.5.7.1.1 Cutting, welding, or spark-producing operations shall be permitted only in the areas where all machinery is shut down and where the area is thoroughly cleaned and inspected to ensure the removal of all accumulations of combustible aluminum dust.

6.5.7.1.2 Lockout/tagout procedures shall be followed for the shutdown of machinery.

6.5.7.1.3 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*.

6.5.7.2 Smoking materials, matches, and lighters shall not be carried or used by employees or visitors on the premises adjacent to or within any building in which combustible aluminum dust is present.

6.5.7.3* 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.

6.5.7.4 Nonsparking tools shall be used to make repairs or adjustments on or around any machinery or apparatus where combustible aluminum dust is present.

6.5.7.5 Dressing of grinding wheels shall not be conducted when the airflow across the grinding wheel is entering a combustible aluminum dust collection system.

6.5.7.6 Spark-producing operations shall be separated from any cleaning equipment using flammable or combustible solvents and shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

6.5.7.7 Cleaning Tools.

6.5.7.7.1 Brooms and brushes used for cleaning shall have natural fiber bristles.

6.5.7.7.2 Synthetic bristles shall not be used.

6.5.7.7.3 Scoops, dustpans, and so forth used for collecting sweepings shall be made of nonsparking, conductive material.

6.5.7.8 Dry aluminum sweepings shall not be returned to the main process stream for processing.

6.5.8 Compressed Air Fittings. To prevent potential explosions caused by inadvertently using compressed air in place of inert gas, fittings used on compressed air and inert gas–line outlets shall not be interchangeable.

6.6 Safety Procedures.

6.6.1 Scope. Section 6.6 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

6.6.2 Personal Protective Equipment.

6.6.2.1 Outer clothing shall be clean, flame retardant, and non–static generating where combustible aluminum dust is present and shall be designed to be easily removable.

(A) Tightly woven, smooth fabrics treated with a flame-retardant chemical and from which dust can readily be brushed shall be used if necessary.

(B) Wool, silk, or synthetic fabrics that can accumulate high static electric charges shall not be used.

6.6.2.2 Work clothing shall be designed to minimize the accumulations of combustible aluminum dust (e.g., trousers shall not have cuffs).

6.6.2.3* Safety shoes shall be static-dissipating, where necessary, shall have no exposed metal, and shall be appropriate for the type of operation taking place.

6.6.2.4* Clothing Fires.

6.6.2.4.1 Emergency procedures for handling clothing fires shall be established.

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

6.6.3 Emergency Procedures.

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

6.6.3.2* All employees shall be trained in the emergency procedures specified in 6.6.3.1.

6.6.4 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.

(A) The inspection shall be conducted at least quarterly but shall be permitted to be done more often.

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

Chapter 7 Magnesium

7.1 Location and Construction of Magnesium Powder Production Plants.

7.1.1 Location.

7.1.1.1 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.

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

7.1.1.3 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 pressure of 13.8 kPag (2.0 psig) and is non–load-bearing, noncombustible, and without openings.

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

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

7.1.2 Security.

7.1.2.1 Application.

7.1.2.1.1 Subsection 7.1.2 shall apply to new and existing magnesium powder production plants.

7.1.2.1.2 The intent of 7.1.2 shall be to restrict access by the general public to magnesium powder production plants and to establish adequate exits for personnel.

7.1.2.2 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.

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

7.1.3 Building Construction.

7.1.3.1 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.

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

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

7.1.3.2 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.

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

7.1.3.4 The requirements of 7.1.3.3 shall also apply to elevated platforms, balconies, floors, and gratings.

7.1.3.5 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.

7.1.3.6 Roof decks shall be watertight.

7.1.4 Doors and Windows.

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

7.1.4.2 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*.

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

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

7.1.6 Electrical Power.

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

7.1.6.2* In local areas of a plant where a hazardous quantity of 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*.

7.1.6.3 Buildings shall be provided with emergency lighting systems in accordance with NFPA *101*, *Life Safety Code*.

7.1.6.3.1 The emergency lighting shall be energized automatically on loss of electrical power to the buildings.

7.1.6.3.2 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.

7.2 Magnesium Mill and Foundry Operations.

7.2.1* Melting and Casting Operations.

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

7.2.1.1.1 Melt rooms shall provide access to facilitate fire control.

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

7.2.1.2* 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.

7.2.1.3 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.

7.2.1.4* Prevention of Molten Magnesium Contact with Foreign Materials.

7.2.1.4.1 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.

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

7.2.1.4.3 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.

7.2.1.4.4 Melting pots and crucibles shall be inspected regularly.

7.2.1.4.5 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.

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

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

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

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

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

7.2.2* Heat Treating.

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

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

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

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

(A) One set of temperature controls shall maintain the desired operating temperature.

(B)* The other set of temperature controls, operating as a high-temperature limit control, shall cut off fuel or power to the heat-treating furnace at a temperature above the desired operating temperature.

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

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

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

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

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

7.2.2.10* 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.

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

7.3 Machining, Finishing, and Fabrication of Magnesium.

7.3.1* Machining.

7.3.1.1 Cutting tools shall not be permitted to ride on the metal without cutting, because frictional heat can ignite any fine metal that is scraped off.

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

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

7.3.1.2* 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.

7.3.1.3 Relief shall be maintained on tools used in grooving and parting operations, because the tool tends to rub the sides of the groove as it cuts.

(A) Side relief shall be 5 degrees.

(B) End relief shall be from 10 degrees to 20 degrees.

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

7.3.1.4.1 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.

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

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

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

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

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

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

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

(B) All chips shall be stored in covered noncombustible containers and removed to a storage area in accordance with Section 7.7.

7.3.1.6.4 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.

7.3.2 Dust Collection.

7.3.2.1 Hoods.

7.3.2.1.1 Dust shall be collected by means of suitable hoods or enclosures at each operation.

7.3.2.1.2 Hoods and enclosures shall be connected either to a wet-type collector or to a cyclone collector and blower located outdoors.

7.3.2.2 The dust collection system shall be designed and installed so that the dust is collected upstream of the fan.

7.3.2.3 The use of dry media–type collectors shall be prohibited.

7.3.2.4 Wet-Type Dust Collectors.

7.3.2.4.1* Where wet-type dust collectors are used, the unit shall be designed so that the dust collected is converted to sludge without contact, in the dry state, with any high-speed moving parts.

7.3.2.4.2* Wet-type dust collectors shall be restricted to a dust loading of no more than 175 grains/m^3 (5 grains/ft^3) of inlet air on standard configuration collectors.

7.3.2.4.3 Wet-type dust collectors shall be designed such that the hydrogen being generated from the magnesium contacting the water is vented at all times.

7.3.2.4.4 Means of venting to avoid accumulation of hydrogen shall be maintained. Each chamber of the collector shall be vented to dissipate the hydrogen.

7.3.2.4.5 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.

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

7.3.2.4.7 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.

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

7.3.2.4.9 Downdraft bench configuration collectors shall maintain no less than 90 m/min (300 ft/min) average work-surface capture velocity at each work station, with work-surface capture velocity determined as a function of nominal work surface area.

7.3.2.4.10* Each wet-type dust collector shall be dedicated to the collection of magnesium or magnesium alloy only.

7.3.2.5 Cyclone Dust Collectors.

7.3.2.5.1 Hoods and enclosures shall be connected to a high-efficiency cyclone(s) and blower located outdoors.

7.3.2.5.2 The cyclone exhaust shall terminate in a safe, outdoor location.

7.3.2.5.3 Recycling of air from any dust collector into buildings shall be prohibited.

7.3.2.5.4 All components of a dust collection system shall be made of conductive materials and shall be watertight.

7.3.2.5.5 The minimum length of duct from the dust-producing operation(s) to the cyclone shall be 4.7 m (15 ft).

7.3.2.5.6* Explosion venting shall be permitted to be installed on dry-type dust collection systems.

7.3.2.6 Ductwork.

7.3.2.6.1 The discharge duct for wet-type dust collection equipment shall terminate at a safe, outdoor location.

7.3.2.6.2 Recycling of air from any dust collector into buildings shall be prohibited.

7.3.2.6.3 The ductwork and fan system shall be designed such that the concentration of magnesium dust in the system is less than 25 percent of the minimum explosible concentration (MEC).

7.3.2.6.4 In systems that involve multiple machines connected to one dust collector, the concentration limit and velocity requirement shall be met throughout the entire system.

7.3.2.6.5 All components of the dust collection system shall be of conductive material.

7.3.2.6.6 Connecting ducts or suction tubes between points of collection and dust collectors shall be completely bonded and grounded.

7.3.2.6.7 Ducts and tubes shall be as short as possible, with no unnecessary bends.

7.3.2.6.8 Ducts shall be fabricated and installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

7.3.2.6.9 Ducts shall have no unused capped connections to the main trunk line where magnesium dust can accumulate.

7.3.2.6.10 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 wet-type dust collector, so that improper functioning of the dust collection system will shut down the equipment it serves.

7.3.2.6.11 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the dust collector is in complete operation.

7.3.3 Cleaning.

7.3.3.1 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.

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

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

7.3.4 Electrical Equipment.

7.3.4.1* In local areas of a plant where a hazardous quantity of 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.*

7.3.4.2 All electrical equipment shall be inspected and cleaned periodically.

7.3.4.3 Where flashlights or electrical devices are used, they shall be listed for classified locations.

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

7.3.6 Safety Precautions.

7.3.6.1 Operator clothing shall be flame retardant and easily removable and kept clean and dust free.

(A) Clothing shall be smooth, allowing dust to be brushed off readily.

(B) Clothing shall have no pockets or cuffs.

(C) Wool, silk, or fuzzy outer clothing and shoes with exposed steel parts shall be prohibited.

7.3.6.2 Machinery and equipment described in 7.4.2 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.

7.3.6.3* No open flames, electric or gas cutting or welding, or other spark-producing operations shall be permitted in the section of the building where magnesium dust is produced or handled while dust-producing equipment is in operation.

7.3.6.3.1 In areas where the type of work specified in 7.3.7 is done, all machinery shall be shut down, and the area shall be thoroughly cleaned to remove all accumulations of magnesium dust.

7.3.6.3.2 All internal sections of grinding equipment, ducts, and dust collectors shall be completely free of moist or dry magnesium dust, and any hydrogen shall be flushed out.

7.3.6.3.3 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.*

7.3.6.4* Grinding Wheels.

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

7.3.6.4.2 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.

7.3.6.5 Nonsparking tools shall be used for making repairs or adjustments around grinding wheels, hoods, or collector units where magnesium dust is present.

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

7.3.7 Drawing, Spinning, and Stamping.

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

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

7.3.7.3 Fine particles shall be handled according to the requirements of Section 7.4.

7.4 Magnesium Powder — Machinery and Operations.

7.4.1 General Precautions.

7.4.1.1 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).

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

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

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

7.4.2 Requirements for Machinery.

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

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

7.4.2.2.1 The requirement of 7.4.2.2 shall apply to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled.

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

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

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

7.4.2.5 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.

7.4.3 Start-up Operations. All the machine-processing contact areas shall be thoroughly cleaned and free from water before being charged with metal and placed into operation.

7.4.4 Charging and Discharging.

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

7.4.4.2 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.

7.4.5 Packaging and Storage.

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

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

7.5 In-Plant Conveying of Magnesium Powder.

7.5.1 Containers.

7.5.1.1* In-plant transfer of powders shall be done in covered conductive containers, as described in Section 7.4.

7.5.1.2 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 7.3.4.1.

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

7.5.2 Pneumatic Conveying.

7.5.2.1 If the conveying gas is air, the magnesium dust-to-air ratio throughout the conveying system shall be held safely below the MEC of the magnesium dust at normal operating conditions. *(See 7.3.2 and Annex C.)*

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

7.5.2.3 The inert gas used shall be based on such gases as argon (Ar), carbon dioxide (CO_2), helium (He), nitrogen (N), or flue gas and shall have a limiting oxygen concentration (LOC) determined by test to be appropriate to the inerting gas.

7.5.2.4 The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

7.5.2.5* A minimum conveying velocity of 1078 m/min (3500 ft/min) 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 an unscheduled system stoppage.

7.5.3 Ductwork for Conveying Systems.

7.5.3.1* Deflagration venting by the use of means such as rupture diaphragms shall be provided on ductwork.

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

7.5.3.1.2 Ductwork provided with explosion isolation systems identified in NFPA 69, *Standard on Explosion Prevention Systems*, shall be designed to prevent propagation of a deflagration into another part of the process.

7.5.3.2* Wherever damage to other property or injury to personnel can result from the rupture of the ductwork, and where explosion relief vents cannot provide sufficient pressure relief, the ductwork shall be designed to withstand a sudden internal gauge pressure of 872 kPa (125 psi).

7.5.3.3 If a portion of the ductwork is so located that no damage to property or injury to personnel can result from its bursting, that portion shall be permitted to be of light construction so as to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

7.5.3.4 Conveyor ducts shall be constructed of conductive material.

7.5.3.5 Nonconductive duct liners shall not be used.

7.5.3.6* Ducts shall be electrically bonded and grounded to minimize the accumulation of static electric charge. *(See 7.4.2.2.)*

7.5.3.7 Where the conveying duct is exposed to weather or moisture, it shall be moisturetight.

7.5.4 Fan Construction and Arrangement.

7.5.4.1* Blades and housings of fans used to move air or inert gas in conveying ducts shall be constructed of conductive, nonsparking metal such as bronze, nonmagnetic stainless steel, or aluminum.

7.5.4.2 Personnel shall not be permitted within 15 m (50 ft) of the fan while it is operating, except as permitted in 7.5.4.2.2.

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

7.5.4.2.2 If personnel must approach the fan while it is operating, such as for a pressure test, it shall be done under the direct supervision of a competent technical person, with the knowledge and approval of operating management, and with the flow of magnesium stopped.

7.5.4.2.3 Where the aluminum powder–conveying system is inerted, personnel shall be permitted to be closer than 15 m (50 ft).

7.5.4.3 Fans shall be located outside all buildings and located so that the entrance of dust from the fan exhaust into any building is minimized.

7.5.4.4 Fans shall be electrically interlocked with dust-producing machinery so that the machines shut down if the fans stop.

7.5.5 Dust Collectors.

7.5.5.1 Dry-dust collectors shall be located outside, in a safe location, and shall be provided with barriers or other means for protection of personnel. *(See A.6.3.2.5.2.)*

7.5.5.2 The area around the collector shall be posted with the following sign:

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

7.5.5.3 Ductwork shall comply with the provisions of 7.5.3.

7.5.5.4* The entire dust collection system, including the dust collector, shall be constructed of conductive material and shall be completely bonded and grounded to minimize the accumulation of static electric charge.

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

7.5.5.5.1 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.

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

7.5.5.6 Repairs.

7.5.5.6.1 Where repairs to dry-dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed. *(See Section 7.7.)*

7.5.5.6.2 Ductwork leading into the collector shall be disconnected and blanked off before repair work is started.

7.6 Prevention of Fugitive Dust Accumulations.

7.6.1 General.

7.6.1.1 Fugitive dust shall not be allowed to accumulate.

7.6.1.1.1 Spills shall be removed at once, using conductive, nonsparking scoops and soft brooms or brushes having natural fiber bristles.

7.6.1.1.2 Compressed-air blowdown shall not be permitted.

7.6.1.2* Vacuum Cleaning Systems.

7.6.1.2.1 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.

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

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

7.6.1.2.4* Portable vacuum cleaners shall be used only if listed or approved for use with combustible magnesium dust.

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

7.6.1.2.5.1 Assembled components shall be conductive and bonded where necessary.

7.6.1.2.5.2 Periodic tests for continuity shall be performed.

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

7.6.2 Cleaning Frequency.

7.6.2.1 Operating personnel and supervisors shall exercise great care to prevent the accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned during daily operations.

7.6.2.2 Regular periodic cleaning, with all machinery idle and power off, shall be performed as frequently as conditions warrant.

7.7 Storage of Magnesium Solids.

7.7.1* Storage of Pigs, Ingots, and Billets.

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

(A) Minimum aisle widths shall be based on the height of the pile per 7.7.1.2.4.

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

7.7.1.2 Yard (Outdoor) Storage.

7.7.1.2.1 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.

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

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

7.7.1.2.3.1 In no case, other than under the conditions of 7.7.1.2.3.2, shall the amount of magnesium stored exceed 45,400 kg (100,000 lb).

7.7.1.2.3.2 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.

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

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

7.7.1.2.6 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.

7.7.1.3* Indoor Storage.

7.7.1.3.1 Indoor storage shall be in buildings of noncombustible construction.

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

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

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

7.7.1.3.4.1 In no case, other than under the conditions of 7.7.1.3.4.2, shall the amount of magnesium stored exceed 23,000 kg (50,000 lb).

7.7.1.3.4.2 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.

7.7.1.3.5 Aisle widths shall comply with 7.7.1.2.4.

7.7.1.3.6 Combustible material shall not be stored within a distance of 7.7 m (25 ft) from any pile of magnesium pigs, ingots, and billets.

7.7.2 Storage of Heavy Castings.

7.7.2.1 Except under the conditions of 7.7.2.2, buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

7.7.2.2 Storage shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system.

7.7.2.3* Floors shall be of noncombustible construction and shall be well drained to prevent accumulations of water in puddles.

7.7.2.4 All magnesium castings shall be clean and free of chips or fine particles of magnesium when being stored.

7.7.2.5 Storage Piles.

7.7.2.5.1 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).

7.7.2.5.2 Aisles shall be maintained to allow inspection and effective use of fire protection equipment.

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

7.7.2.7* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or other packing materials are present.

7.7.3 Storage of Light Castings.

7.7.3.1 Building Construction.

7.7.3.1.1 Except under the conditions of 7.7.3.1.2, light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage by 7.7 m (25 ft).

7.7.3.1.2 Storage of light castings shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system. *(See 7.7.3.5.)*

7.7.3.2 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).

7.7.3.3 Light castings shall be segregated from other combustible materials and shall be kept away from flames or sources of heat capable of causing ignition.

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

7.7.3.5* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

7.7.4 Storage in Racks or Bins.

7.7.4.1 Racks shall be permitted to be extended along walls in optional lengths.

7.7.4.2 Aisle spaces in front of racks shall be equal to the height of the racks.

7.7.4.3 All aisle spaces shall be kept clear.

7.7.4.4 Combustible rubbish, spare crates, and separators shall not be allowed to accumulate within the rack space.

7.7.4.5 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.

7.7.5 Storage of Scrap Magnesium.

7.7.5.1 Subsection 7.7.5 shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

7.7.5.2 Buildings used for the indoor storage of magnesium scrap shall be of noncombustible construction.

7.7.5.3 Dry magnesium scraps shall be kept well separated from other combustible materials.

7.7.5.3.1 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.

7.7.5.3.2 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.

7.7.5.4* Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

(A) Sources of ignition shall be kept away from the drum vent and top.

(B) Containers shall not be stacked.

7.7.5.5 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.

7.7.5.6 Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers pending salvage.

7.7.5.7 Oily rags, packing materials, and similar combustibles shall not be permitted in storage bins or areas that store solid magnesium scrap.

7.7.5.8 The use of automatic sprinklers in magnesium scrap storage buildings or areas shall be prohibited.

7.7.6 Storage of Magnesium Powder.

7.7.6.1 Buildings used to store magnesium powder shall be of noncombustible, single-story construction.

7.7.6.2 The use of automatic sprinklers in magnesium powder storage buildings shall be strictly prohibited.

7.7.6.3 Magnesium powder shall be kept well separated from other combustible or reactive metals.

7.7.6.4 Magnesium powder shall be stored in closed steel drums or other closed noncombustible containers, and the containers shall be stored in dry locations.

7.7.6.5 Magnesium powder storage areas shall be kept dry and shall be checked for water leakage.

7.7.6.6* In local areas of a plant where a hazardous quantity of 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.*

7.7.6.7* Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 5.5 m (18 ft).

(A) Storage shall be stacked in a manner that ensures stability.

(B) Under no circumstances shall containers be allowed to topple over.

7.7.7 Storage of Other Magnesium Products.

7.7.7.1* Subsection 7.7.7 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.

7.7.7.2 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.

7.7.7.3 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).

7.7.7.4* 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

7.8 Fire Prevention. The provisions of Section 7.8 shall apply to all new and existing magnesium production processing, handling, and storage operations.

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

7.8.2* Hot Work.

7.8.2.1 Hot-work permits shall be required in designated areas that contain exposed magnesium chips, powder, or sponge.

7.8.2.2 All hot-work areas that require a permit shall be thoroughly cleaned of magnesium chips, powder, or sponge before hot work is performed.

7.8.3* All containers used to receive molten magnesium shall be cleaned and dried thoroughly before use.

7.8.4 Good housekeeping practices shall be maintained.

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

7.8.4.2 Supplies of materials in magnesium-processing areas shall be limited to those amounts necessary for normal operation.

7.8.5 Ordinary Combustible Materials.

7.8.5.1 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in magnesium-processing areas.

7.8.5.2 The requirement of 7.8.5.1 shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

7.8.6* Magnesium Chips or Powder.

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

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

7.8.7 Inspections.

7.8.7.1 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.

7.8.7.2 Records of the inspections specified in 7.8.7.1 shall be kept.

7.8.8* Ordinary combustible materials shall not be discarded in containers used for the collection of 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.

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

7.8.10 Smoking shall not be permitted in areas where ignitable magnesium chips or powder is present.

(A) Areas in which ignitable magnesium chips or powder is present shall be posted with "No Smoking" signs.

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

7.8.11 All electrical equipment and wiring in magnesium production, processing, handling, and storage facilities shall comply with *NFPA 70, National Electrical Code*.

7.8.12 Where tools and utensils are used in areas handling magnesium powder, consideration shall be given to the risks associated with generating impact sparks and static electricity.

7.8.13* Processing equipment used in magnesium operations shall be electrically bonded and grounded properly to prevent accumulations of static electricity.

7.8.14 Where magnesium 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.

Chapter 8 Niobium

8.1 Construction of Production Plants.

8.1.1 Plant Construction.

8.1.1.1 Buildings for the storage, handling, processing, or use of niobium in a combustible form shall be constructed of noncombustible materials.

8.1.1.2 All buildings shall be of Type I or Type II construction, as defined in NFPA 220, *Standard on Types of Building Construction*.

8.1.1.3 Floors in facilities shall be made of noncombustible materials.

8.1.1.3.1* 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.

8.1.1.3.2 The hazards analysis shall specifically consider the combustibility and specific character of the materials being handled in the facility.

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

8.1.1.3.4 Roof decks shall be watertight.

8.1.2 Drying Rooms.

8.1.2.1 Drying rooms shall be of Type I construction as defined by NFPA 220, *Standard on Types of Building Construction*.

8.1.2.2 Drying rooms shall be segregated as far as is practical from other operations.

8.1.2.3 A hazards analysis shall be performed to determine whether deflagration venting is needed in drying rooms.

8.1.2.4 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.

8.1.2.5 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*.

8.1.2.6 Openings in fire walls and fire barrier walls shall be protected in accordance with NFPA 80, *Standard for Fire Doors and Other Opening Protectives*.

8.1.2.7 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.

8.1.2.8 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.

8.1.2.9* Water pipes or pipes that can contain water for uses other than process or production support (e.g., sprinkler piping, domestic water, 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.

8.1.3 Grounding of Equipment.

8.1.3.1 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.

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

8.1.3.3* 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.

8.1.4 Electrical Power.

8.1.4.1* All electrical equipment and wiring shall be installed in accordance with *NFPA 70, National Electrical Code*, and NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*.

8.1.4.2 An inspection schedule acceptable to the authority having jurisdiction shall be established to ensure that existing enclosures for electrical equipment not purged or pressurized are effective in preventing accumulation of niobium dust within the electrical enclosures.

8.1.4.3* In local areas of a plant where a hazardous quantity of 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.*

8.1.4.4* All hazardous (classified) areas identified in accordance with 8.1.4.3 shall be documented, and such documentation shall be maintained on file for the life of the facility.

8.1.5 Explosion Mitigation/Venting.

8.1.5.1 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.

8.1.5.2* 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.

8.1.5.2.1* 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.

8.1.5.2.2* Relief valves shall not be vented to a dust hazard area.

8.1.5.2.3 Equipment shall be located or arranged in a manner that minimizes combustible dust accumulations on surfaces.

8.1.6 Management of Change.

8.1.6.1 The requirements of 8.1.6.2 through 8.1.6.5 shall apply to existing facilities and processes.

8.1.6.2 Written procedures shall be established and implemented to manage a proposed change to process materials, technology, equipment, procedures, and facilities.

8.1.6.3 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
(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

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

8.1.6.5 Design documentation shall be updated to incorporate the change.

8.2 Melting Operations for Primary Producers.

8.2.1* Explosion Prevention.

8.2.1.1* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

8.2.1.2 Sealed vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the vessel.

8.2.1.2.1* 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.

8.2.1.2.2 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.

8.2.2 Upper Chamber of the Furnace.

8.2.2.1* The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.

8.2.2.2 Means shall be provided to prevent the influx of air through the pressure-relief port.

8.2.2.3 Large low-pressure ports shall not be used.

8.2.2.4* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

8.2.2.5* The furnace shall be equipped with a device that continuously senses pressure within the furnace.

8.2.2.5.1 The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

8.2.2.5.2 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

8.2.2.5.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

8.2.2.6* Water-cooled crucibles shall be inspected to ensure that minimum wall thicknesses are maintained to prevent a breach of the crucible wall.

8.2.3* Water Supply.

8.2.3.1 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.

8.2.3.2 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.

8.2.3.3 Equipment construction shall mitigate the potential for ignition of the niobium powder.

8.2.3.4 All electrically operated or controlled processing equipment shall be installed in accordance with *NFPA 70, National Electrical Code.*

8.2.3.5 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

8.2.3.6 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

8.2.4 Casting.

8.2.4.1 Water Supply.

8.2.4.1.1 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.

8.2.4.1.2 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.

8.2.4.2* Molds.

8.2.4.2.1 Molds for niobium casting shall be made of material that is compatible with molten niobium.

8.2.4.2.2 Molds shall be dried thoroughly and shall be stored to prevent accumulation of moisture in the molds.

8.2.4.2.3 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.

8.2.4.2.4* Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

8.2.4.3* Residue.

8.2.4.3.1 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.

8.2.4.3.2 The containers specified in 8.2.4.3.1 shall be stored so that any hydrogen gas generated vents freely.

8.2.5 Personnel Safety Precautions.

8.2.5.1 Molten niobium shall be contained in closed systems that prevent its unintentional contact with air or reactive materials.

8.2.5.2 Personnel involved in niobium melting operations with the potential for exposure to molten niobium shall wear appropriate personnel protective equipment (PPE).

8.2.5.3 Niobium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium.

8.2.6* Machining Operations and Fabrication Operations.

8.2.6.1* Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of niobium.

8.2.6.2 All electrically operated or controlled processing equipment shall be installed in accordance with *NFPA 70, National Electrical Code.*

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

8.2.6.3.1 The pan or tray shall be installed so that it is accessible for chip, turning, or compacted niobium powder removal and for application of extinguishing agent to control a fire.

8.2.6.3.2 The pan construction shall be sufficient to minimize the potential for burn-through.

8.2.6.3.3 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.

8.2.6.3.4* Cutting tools shall be designed for use with niobium and shall be kept sharp.

8.2.6.3.5* 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).

8.2.6.3.6* Flammable or combustible liquids shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

8.2.6.3.7 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

8.2.6.3.8 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).

8.2.6.3.9 The collected solids shall be moved to a designated storage or disposal area.

8.2.6.3.10 Crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily to a designated storage or disposal area.

8.2.6.3.11 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.

8.2.6.3.12 A hazards analysis shall be conducted to ensure that these operations do not contribute to fugitive dust accumulation.

8.2.6.3.13 If dust collection is used for grinding and sanding applications, take-up hoods shall be designed to minimize the accumulation of dust.

8.3* Hot Work. 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.

8.4 Niobium Powder Manufacturing for Primary Producers.

8.4.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for ignition of the niobium.

8.4.2* Only niobium powder for immediate use shall be present in handling areas.

8.4.2.1 Daily supplies of niobium powder shall be allowed to be stored in the production area.

(A) The niobium powder shall be stored in covered containers and shall be segregated from other combustible materials.

(B) The maximum capacity of the container shall be such that it can be moved by available equipment.

(C) The containers shall be protected from damage.

8.4.3 Transport of dry niobium powders within manufacturing operations and storage of dry niobium powders within manufacturing areas shall be done in covered conductive containers.

8.4.4 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 8.1.4.3.

8.4.5 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.

8.5 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.

8.5.1* Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

8.5.2 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).

8.5.3* 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.

8.5.4 Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.

8.5.5 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.

8.6* Dryers.

8.6.1 Dryers shall be constructed of noncombustible materials.

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

8.6.3 Outward opening access doors or openings shall be provided in all parts of the dryer and connecting conveyors to allow inspection, cleaning, maintenance, and the effective use of extinguishing agents.

8.6.4 Explosion protection shall be provided as specified in 8.4.5.

8.6.5* 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.

8.6.6 Heated dryers shall have operating controls configured to maintain the temperature of the drying chamber within the prescribed limits.

8.6.7 Excess temperature–limit controls required in 8.6.6 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

8.6.8 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 8.6.7.

8.6.9 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

8.6.10 All automatic shutdowns required by 8.6.8 shall require manual reset before the dryer can be returned to operation.

8.6.11 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.

8.7 Niobium Powder Handling.

8.7.1* Where niobium powder is present, good housekeeping practices shall be maintained.

8.7.2 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.

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

8.7.4* Scoops, shovels, and scrapers used in the handling of dry niobium powder shall be electrically conductive and shall be bonded or grounded.

8.7.5 Hand tools used in handling dry niobium powder shall be made of spark-resistant materials.

8.7.6 Care shall be exercised to avoid the presence of an isolated conductor in the vicinity of niobium powder being handled.

8.7.7* The use of humidifiers in facilities where dry niobium powder is handled shall be considered.

8.7.8 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*.

8.7.9 Niobium powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

8.7.10 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

8.8 Electrical Installations.

8.8.1* All niobium powder production, drying, and packaging areas shall be evaluated for fire and explosion hazards associated with the operation and shall be provided with approved electrical equipment suitable for the location.

8.8.2 The electrical equipment shall be installed in accordance with the requirements of Article 500 of *NFPA 70*, *National Electrical Code*.

8.8.3 Where dry niobium powders are charged to or discharged from equipment, the containers shall be bonded or grounded.

8.8.4 Only conductive containers shall be used for the processing of niobium powders.

8.8.5 When dry niobium powder is transferred between containers, the containers shall be bonded and grounded.

8.9 Explosion Prevention and Protection.

8.9.1* 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.

8.9.1.1 Where explosion protection is required per 8.9.1, 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*

8.9.1.2 If the method specified in 8.9.1.1(5) is used, test data for the specific dust and dilution combinations shall be provided and shall be acceptable to the authority having jurisdiction.

8.9.1.3 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.

8.9.1.4 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.

8.9.2* Inerting. A supply of argon or helium as an inerting agent shall be provided on site at all times for blanketing and purging equipment.

8.9.3 Electrical Equipment. All electrical wiring and equipment shall comply with Article 500 of *NFPA 70, National Electrical Code.*

8.9.4 Personnel Safety Precautions.

8.9.4.1* 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 are not required.

8.9.4.2 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.

8.9.4.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in case of primary system failure.

8.9.4.4* Niobium powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium powder.

8.9.4.5 Access to niobium powder–handling areas by unauthorized personnel shall not be permitted.

8.10* Housekeeping Practices.

8.10.1 Good housekeeping practices shall be followed so that accumulations of niobium powder are minimized.

8.10.2 Special attention shall be paid to niobium powder accumulations in crevices and joints between walls and floors. (*See 8.9.4.4.*)

8.11 Niobium Powder End Users.

8.11.1 Equipment shall be constructed to mitigate the potential for ignition of niobium powder.

8.11.2* All electrical wiring and equipment shall be installed in accordance with *NFPA 70, National Electrical Code*, and all components of equipment shall be electrically bonded and grounded.

8.11.3 A hazards analysis shall be performed for areas where niobium powder is present to determine risk factors and applicable controls.

8.11.4 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.

8.11.5* 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.

8.11.6* Spark-resistant tools shall be used.

8.11.7 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

8.12* Niobium Powder Storage.

8.12.1 Niobium powder–handling or niobium powder–processing areas shall not be used for primary storage of niobium.

8.12.1.1 Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in niobium-processing areas.

8.12.2 Stacked Storage.

8.12.2.1 Where niobium powder is stored in sealed containers, stacked storage shall be arranged to ensure stability.

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

8.12.3 Dry Niobium Powder Handling.

8.12.3.1 Precautions shall be taken to prevent spills or dispersions that produce niobium dust clouds.

8.12.3.2 Sintering furnaces that handle compacted niobium powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces.*

8.12.3.2.1 Niobium powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

8.12.3.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

8.12.4 Wet Niobium Powder Handling. Water-wetted powder, when air dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

8.12.4.1 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).

8.12.4.2 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.

8.12.5 Heat Treatment and Passivation.

8.12.5.1 General.

8.12.5.1.1 Equipment shall be designed, constructed, installed, and operated to mitigate the potential for accumulation and ignition of niobium.

8.12.5.1.2 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*.

8.12.5.1.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces*.

8.12.5.2 Electrical Installations. The electrical equipment shall be installed in accordance with the requirements of *NFPA 70, National Electrical Code*.

8.12.6 Personnel Safety Precautions.

8.12.6.1 Niobium metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with niobium.

8.12.6.2 Access to niobium-handling areas by unauthorized personnel shall not be permitted.

8.12.6.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

8.12.7 Niobium Powder Heat Treatment and Sintering.

8.12.7.1* After niobium powder furnacing, the niobium powder shall be passivated prior to exposure to air atmosphere.

8.12.7.2 Furnaced niobium powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

8.12.7.3 Furnaced niobium powder shall be monitored during passivation to ensure that uncontrolled oxidation, resulting in unacceptable temperature increase of the niobium, does not occur.

8.12.8* Heat Treatment and Sintering of Niobium Compacts.

8.12.8.1 Sintered niobium compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

8.12.8.2 Sintered niobium compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

8.12.9 Safety Precautions.

8.12.9.1 If the furnace primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cooldown time period.

8.12.9.2 The alternative cooling system specified in 8.12.9.1 shall be activated automatically on failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

8.13 Dust Collecting for Niobium Operations.

8.13.1 Dust-Producing Operations.

8.13.1.1 Machines that produce fine particles of niobium 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.

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

(B) Dust shall be collected by means of suitable hoods or enclosures at each operation.

8.13.1.2* 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 are as straight as possible.

8.13.1.3 Dust collection systems handling niobium shall be provided with explosion protection as required under 8.4.5.

8.13.2 Dust-Collecting Ducts and Ductwork.

8.13.2.1 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*.

8.13.2.2 Ducts shall be designed to maintain a velocity of not less than 1365 m/min (4500 ft/min) to ensure the transport of both coarse and fine particles and to ensure re-entrainment if, for any reason, the particles fall out before delivery to the collector (e.g., in the event of a power failure).

8.13.2.3 Ducts shall be designed to handle a volumetric flow rate that maintains dust loading safely below the MEC.

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

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

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

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

8.13.2.5.3 Additional branch ducts shall not be added to an existing system without redesign of the system.

8.13.2.5.4 Branch ducts shall not be disconnected, and unused portions of the system shall not be blanked off, without provision of means to maintain required airflow.

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

8.13.3* Wet-Type Dust Collectors.

8.13.3.1 The exhaust vent shall terminate outside the building and shall be fastened securely.

8.13.3.2 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.

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

8.13.3.4 The dust collector shall be arranged so as to prevent contact between dust particles and parts moving at high speed.

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

8.13.3.6* The dust collector shall be arranged so that the dust-laden air stream shall be thoroughly scrubbed by the liquid to achieve the desired efficiency.

8.13.4 Collector Sump Venting. The sump of water wet-type dust collectors shall be ventilated at all times.

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

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

8.13.4.3 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 activate visual and audible alarms at the equipment it serves and at an area that is occupied at all times that the equipment is in operation.

8.13.4.4 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the collector is in complete operation.

8.13.5* Dry-Type Dust Collectors.

8.13.5.1 Electrostatic and media collectors shall not be used.

8.13.5.2 Dry-type cyclone dust collectors shall be located outside buildings.

8.13.5.3 Dry dust collection systems shall be designed and maintained so that internal cleanliness is ensured.

8.13.5.3.1 The accumulation of material inside any area of the collector other than in the discharge containers designed for that purpose shall not be permitted.

8.13.5.3.2 Accumulation or condensation of water at any point in the dry dust collection system shall be prevented.

8.13.5.4 Dust shall be removed from the dry collectors at the end of each workday and at more frequent intervals if conditions warrant.

(A) Extreme care shall be taken in removing dust from the collectors to avoid creating dust clouds.

(B)* The dust shall be discharged into properly bonded and grounded metal containers that shall be promptly covered to avoid the creation of airborne fugitive dust.

8.13.5.5* The cyclone dust collector shall be of conductive metal construction applicable for the service intended.

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

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

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

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

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

8.13.7 Recycling of Exhaust Air. Recycling of air from dry dust collectors into buildings shall be prohibited.

8.13.8 In-Plant Conveying of Niobium Powder.

8.13.8.1 Power Shutoff. 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.

8.13.8.1.1 Feed to the conveyor shall be stopped or diverted.

8.13.8.2 Enclosed Mechanical Conveyors.

8.13.8.2.1 Housings for enclosed conveyors (e.g., screw and drag conveyors) shall be of metal construction and shall be designed to prevent escape of niobium powders.

8.13.8.2.2 Coverings on clean-out, inspection, and other openings shall be closed and fastened.

8.13.8.2.3 Screw conveyors and bucket elevators that agitate the niobium being transported shall be enclosed in dusttight casings and shall be equipped with explosion prevention or protection methods in accordance with 8.4.5.

8.13.8.3 Pneumatic Conveying.

8.13.8.3.1 Ducts shall be designed to handle a volumetric flow rate that maintains dust loading safely below the MEC.

8.13.8.3.2 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*.

8.13.8.3.3* The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

8.13.8.3.4 Ductwork for conveying systems shall be constructed according to 8.13.8.3.4.1 through 8.13.8.3.4.7.

8.13.8.3.4.1 Nonconductive duct or duct liners shall not be used.

8.13.8.3.4.2 Ducts shall be electrically bonded and grounded.

8.13.8.3.4.3 Deflagration venting (e.g., rupture diaphragms) shall be provided on ductwork.

8.13.8.3.4.4 Deflagration vents shall relieve to a location outside the building.

8.13.8.3.4.5* The design of deflagration venting shall be in accordance with good engineering practice.

8.13.8.3.4.6 Wherever damage to other property or injury to personnel can result from the rupture of the ductwork, and where explosion-relief vents cannot provide pressure relief, the ductwork shall be designed to withstand a sudden internal gauge pressure of 862 kPa (125 psi).

8.13.8.3.4.7 Ductwork located so that no damage to property or injury to personnel can result from its bursting shall be permitted to be of light construction so as to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

8.13.8.4 Fans shall be installed in accordance with the air-moving device requirements of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

8.13.8.4.1 Blades and housings of fans used to move air, argon, or helium in conveying ducts shall be constructed of conductive, nonsparking metal, such as bronze, nonmagnetic stainless steel, or aluminum.

8.13.8.4.2 Fan motors shall be located outside the duct airstream.

8.14 General Storage of Niobium.

8.14.1 Storage with Incompatible Materials. Niobium shall not be stored in an area with incompatible materials.

8.14.2 Scrap Storage.

8.14.2.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

8.14.2.2 Storage of scrap, chips, fines, and dust that are ignitable shall be isolated and segregated from other combustible materials to prevent propagation of a fire.

8.14.3 Powder Storage.

8.14.3.1* Niobium powder shall be stored in covered containers.

8.14.3.2 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.

8.14.3.3 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.

8.14.3.4 Under no circumstances shall stack height exceed 3.1 m (10 ft).

8.14.3.5 Stacked storage shall be arranged to ensure stability.

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

8.14.4 Other Production Materials.

8.14.4.1 Magnesium Operations. All magnesium storage, handling, and processing operations in niobium production operations shall be in accordance with the requirements of Chapter 6.

8.14.4.2 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code.*

Chapter 9 Tantalum

9.1 Construction of Production Plants.

9.1.1 Plant Construction.

9.1.1.1 Buildings for the storage, handling, processing, or use of tantalum in a combustible form shall be constructed of noncombustible materials.

9.1.1.2 All buildings shall be of Type I or Type II construction, as defined in NFPA 220, *Standard on Types of Building Construction.*

9.1.1.3 Where local, state, and national building codes require modifications, such modifications shall be permitted for conformance to these codes.

9.1.1.4 Floors.

9.1.1.4.1 Floors in facilities shall be made of noncombustible materials.

9.1.1.4.2 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.)*

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

9.1.1.6 Roof decks shall be watertight.

9.1.1.7 Drying Rooms.

9.1.1.7.1 Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction.*

9.1.1.7.2 Drying rooms shall be segregated as far as practicable from other operations.

9.1.1.8 A hazards analysis shall be performed to determine whether deflagration venting is needed in drying rooms.

9.1.1.9 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.*

9.1.1.10 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.*

9.1.1.11 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.

9.1.1.12 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.

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

9.1.1.14* Water pipes or pipes that can contain water for uses other than process or production support (e.g., sprinkler piping, domestic water, 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 acceptable to the authority having jurisdiction.

9.1.2* Grounding of Equipment.

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

9.1.2.2 Movable or mobile process equipment of metal construction shall be bonded and grounded prior to use.

9.1.3 Electrical Power.

• **9.1.3.1*** In local areas of a plant where a hazardous quantity of 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.*

9.1.3.2 All hazardous (classified) areas identified in accordance with 9.1.3.1 shall be documented, and such documentation shall be maintained on file for the life of the facility.

9.1.4 Explosion Mitigation and Venting.

9.1.4.1 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.

9.1.4.2* Deflagration Venting.

9.1.4.2.1* 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.

9.1.4.2.2* 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.

9.1.4.3* Relief valves shall not be vented to a dust hazard area.

9.1.4.4 Equipment shall be located or arranged in a manner that minimizes combustible dust accumulations on surfaces.

9.1.5 Management of Change.

9.1.5.1 The requirements of 9.1.5.2 through 9.1.5.5 shall apply to existing facilities and processes.

9.1.5.2 Written procedures shall be established and implemented to manage a proposed change to process materials, technology, equipment, procedures, and facilities.

9.1.5.3 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
(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

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

9.1.5.5 Design documentation shall be updated to incorporate the change.

9.2 Melting Operations for Primary Producers.

9.2.1* Explosion Prevention.

9.2.1.1* Sealed vessels shall be designed and maintained to prevent water from entering the reaction chamber.

9.2.1.2 Sealed vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the vessel.

9.2.1.3* 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.

9.2.1.4 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.

9.2.1.5* Upper Chamber of the Furnace.

9.2.1.5.1 The upper chamber of the furnace shall be provided with a pressure-relieving device to aid in relieving pressure if water enters the furnace.

9.2.1.5.2 Means shall be provided to prevent the influx of air through the pressure-relief port.

9.2.1.5.3 The release pressure of the pressure-relief device shall be 138 kPag (20 psig) maximum.

9.2.1.5.4 Large low-pressure ports shall not be used.

9.2.1.6* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

9.2.1.7 Pressure-Sensing Device.

9.2.1.7.1 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

9.2.1.7.2* The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

9.2.1.8* 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

9.2.1.9 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

9.2.1.10 Water Supply.

9.2.1.10.1 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.

9.2.1.10.2 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.

9.2.1.11 Equipment construction shall mitigate the potential for ignition of the tantalum powder.

9.2.1.12 All electrically operated or controlled processing equipment shall be installed in accordance with *NFPA 70, National Electrical Code.*

9.2.1.13 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

9.2.1.14 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

9.2.2 Casting.

9.2.2.1 Water Supply.

9.2.2.1.1* 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.

9.2.2.1.2 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.

9.2.2.2 Molds.

9.2.2.2.1 Molds for tantalum casting shall be made of material that is compatible with molten tantalum.

9.2.2.2.2* Molds shall be dried thoroughly and shall be stored to prevent accumulation of moisture in the molds.

9.2.2.3 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.

9.2.2.4* Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

9.2.2.5 Residue.

9.2.2.5.1* 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.

9.2.2.5.2 The containers specified in 9.2.2.5.1 shall be stored so that any hydrogen gas generated vents freely.

9.2.3 Personnel Safety Precautions.

9.2.3.1 Molten tantalum shall be contained in closed systems that prevent its unintentional contact with air or reactive materials.

9.2.3.2 Personnel involved in tantalum melting operations shall wear flame-resistant clothing.

9.2.3.3 Tantalum metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum.

9.3* Milling, Machining, and Fabrication Operations.

9.3.1 Machining Operations.

9.3.1.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of tantalum.

9.3.1.2 All electrically operated or controlled processing equipment shall be installed in accordance with *NFPA 70, National Electrical Code*.

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

9.3.1.3.1* 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.

9.3.1.3.2 The pan construction shall be sufficient to minimize the potential for burn-through.

9.3.1.4 In 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.

9.3.1.5* Cutting tools shall be designed for use with tantalum and shall be kept sharp.

9.3.1.6* 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).

9.3.1.7 Flammable or combustible liquids shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

9.3.1.8 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

9.3.1.8.1 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).

9.3.1.8.2 The collected solids shall be moved to a designated storage or disposal area.

9.3.1.9* Crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily to a designated storage or disposal area.

9.3.2* 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 9.10.1.1 for additional requirements.)*

9.4 Tantalum Powder Manufacturing for Primary Producers.

9.4.1 General.

9.4.1.1 Equipment shall be constructed to mitigate the potential for ignition of tantalum.

9.4.1.2* Only tantalum powder for immediate use shall be present in handling areas.

(A) Tantalum powder–handling or tantalum powder–processing areas shall not be used for primary storage of tantalum.

(B) Primary storage of ordinary combustible materials and flammable and combustible liquids shall be prohibited in tantalum-processing areas.

9.4.1.3 Transport of dry tantalum powders within manufacturing operations and storage of dry tantalum powders within manufacturing areas shall be done in covered conductive containers.

9.4.1.4 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 9.1.3.1.

9.4.1.5 To minimize the risk of fire or explosion hazard in the handling of tantalum powders, the equipment and processes shall be designed by persons experienced and knowledgeable in the hazards of tantalum powders.

9.4.2* Drying of Tantalum Powder.

9.4.2.1* Water-wetted powder, when air-dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

9.4.2.2 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).

9.4.2.3 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.

9.4.2.4 Dryers.

9.4.2.4.1 Drying air that contacts material that is being processed shall not be recycled to rooms, processes, or buildings.

9.4.2.4.2 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.

9.4.2.4.3 Dryers shall be constructed of noncombustible materials.

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

9.4.2.4.5 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.

9.4.2.4.6 Explosion protection shall be provided as specified in 9.4.5.

9.4.2.4.7 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.

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

9.4.2.4.9 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

9.4.2.4.10* Excess temperature–limit controls required in 9.4.2.4.9 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

9.4.2.4.11 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 9.4.2.4.10.

9.4.2.4.12 All automatic shutdowns required by 9.4.2.4.10 shall require manual reset before the dryer can be returned to operation.

9.4.3 Tantalum Powder Handling.

9.4.3.1 Where tantalum powder is present, good housekeeping practices shall be maintained.

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

9.4.3.3 Scoops, shovels, and scrapers used in the handling of dry tantalum powder shall be electrically conductive and shall be bonded and grounded.

9.4.3.4 Hand tools used in handling dry tantalum powder shall be made of spark-resistant materials.

9.4.3.5* 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*.

9.4.3.5.1 Tantalum powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

9.4.3.5.2 Furnaces shall be operated with inert atmospheres, such as helium or argon, or under vacuum.

9.4.4 Electrical Installations.

9.4.4.1 All tantalum powder production, drying, and packaging areas shall be evaluated for fire and explosion hazards associated with the operation and shall be provided with approved electrical equipment suitable for the location.

9.4.4.2 The electrical equipment shall be installed in accordance with the requirements of Article 500 of *NFPA 70, National Electrical Code*.

9.4.4.3* Where dry tantalum powders are charged to or discharged from equipment, the containers shall be bonded and grounded.

9.4.4.4 When dry tantalum powder is transferred between containers, the containers shall be bonded and grounded.

9.4.5 Explosion Prevention and Protection.

9.4.5.1* 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.

9.4.5.2 Where explosion protection is required per 9.4.5.1, 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*

9.4.5.3 If the method specified in 9.4.5.2(5) is used, test data for specific dust and dilution combinations shall be provided and shall be acceptable to the authority having jurisdiction.

9.4.5.4 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.

9.4.6* Inerting. A supply of argon or helium, as an inerting agent, shall be provided on-site at all times for blanketing and purging equipment.

9.4.7 Electrical Equipment. All electrical wiring and equipment shall comply with Article 500 of *NFPA 70*, *National Electrical Code*.

9.4.8 Personnel Safety Precautions.

9.4.8.1* Personnel handling tantalum powder shall wear static-dissipative footwear and flame-resistant clothing that is designed to minimize the accumulation of tantalum powder.

9.4.8.2 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

9.4.8.3 Tantalum powder shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum powder.

9.4.8.4* Access to tantalum powder–handling areas by unauthorized personnel shall not be permitted.

9.4.9 Housekeeping Practices.

9.4.9.1 Good housekeeping practices shall be followed so that accumulations of tantalum powder are minimized.

9.4.9.2 Special attention shall be paid to tantalum powder accumulations in crevices and joints between walls and floors. *(See 9.10.3.1.1.)*

9.5 Tantalum Powder End Users.

9.5.1 General.

9.5.1.1* Equipment shall be constructed to mitigate the potential for ignition of tantalum powder.

9.5.1.2* All electrical wiring and equipment shall be installed in accordance with *NFPA 70*, *National Electrical Code*, and all components of equipment shall be electrically bonded and grounded.

9.5.1.3 A hazards analysis shall be performed for areas where tantalum powder is present to determine risk factors and appropriate controls.

9.5.1.4* 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.

9.5.1.5* 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.

9.5.1.6* Spark-resistant tools shall be used.

9.5.1.7 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

9.5.2 Tantalum Powder Storage.

9.5.2.1 Daily supplies of tantalum powder shall be allowed to be stored in the production area.

(A) The tantalum powder shall be stored in covered containers and shall be segregated from other combustible materials.

(B) The maximum capacity of the container shall be such that it can be moved by available equipment.

(C) The containers shall be protected from damage.

9.5.2.2 Stacked Storage.

9.5.2.2.1 When storing tantalum powder in sealed containers, stacked storage shall be arranged to ensure stability.

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

9.5.3 Dry Tantalum Powder Handling.

9.5.3.1* Precautions shall be taken to prevent spills or dispersions that produce tantalum dust clouds.

9.5.3.2 Sintering furnaces that handle compacted tantalum powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces*.

9.5.3.2.1 Tantalum powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

9.5.3.2.2 Furnaces shall be operated with inert atmospheres of argon or helium or under vacuum.

9.5.4 Wet Tantalum Powder Handling.

9.5.4.1* Water-wetted powder, when air-dried at atmospheric pressure, shall be at a temperature not exceeding 80°C (176°F).

9.5.4.2 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).

9.5.4.3 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.

9.6 Heat Treatment and Passivation.

9.6.1 General.

9.6.1.1 Equipment shall be designed, constructed, and installed to mitigate the potential for ignition and accumulation of tantalum.

9.6.1.2 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*.

9.6.1.3 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces*.

9.6.2 Electrical Installations. The electrical equipment shall be installed in accordance with the requirements of *NFPA 70*, *National Electrical Code*.

9.6.3* Personnel Safety Precautions.

9.6.3.1 Tantalum metal shall be handled only by trained personnel who are knowledgeable of the hazards associated with tantalum.

9.6.3.2 Access to tantalum-handling areas by unauthorized personnel shall not be permitted.

9.6.3.3 Backup methods or systems shall be provided to allow for the orderly shutdown of critical processes in the case of primary system failure.

9.6.4 Tantalum Powder Heat Treatment and Sintering.

9.6.4.1 After tantalum powder furnacing, the tantalum powder shall be passivated prior to exposure to air atmosphere.

9.6.4.2 Furnaced tantalum powder shall be cooled to 50°C (122°F) or less prior to starting passivation.

9.6.5* Heat Treatment and Sintering of Tantalum Compacts.

9.6.5.1* Sintered tantalum compacts shall be cooled to 50°C (122°F) or less prior to removal from the furnace.

9.6.5.2 Sintered tantalum compacts shall be isolated from other combustible materials until their temperature has stabilized below 50°C (122°F).

9.6.6 Safety Precautions.

9.6.6.1 If the furnace primary cooling source fails, an alternative system shall provide cooling for the furnace for any required cooldown time period.

9.6.6.2 The alternative cooling system specified in 9.6.6.1 shall be activated automatically upon failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

9.7 Dust Collection for Tantalum Operations.

9.7.1 Dust-Producing Operations.

9.7.1.1 Machines that produce fine particles of tantalum 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.

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

(B) Dust shall be collected by means of suitable hoods or enclosures at each operation.

9.7.1.2* 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 as possible.

9.7.1.3 Dust collection systems handling tantalum shall be provided with explosion protection as required under 9.4.5.

9.7.2 Dust Collection Ducts and Ductwork.

9.7.2.1 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.*

9.7.2.2 Ducts shall be designed to maintain a velocity of not less than 1365 m/min (4500 ft/min) to ensure the transport of both coarse and fine particles and to ensure re-entrainment if, for any reason, the particles fall out before delivery to the collector (e.g., in the event of power failure).

9.7.2.3 Ducts shall be designed to handle a volumetric flow rate that maintains dust loading safely below the MEC.

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

9.7.2.5 Duct Construction.

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

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

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

9.7.2.5.4 Additional branch ducts shall not be added to an existing system without redesign of the system.

9.7.2.5.5 Branch ducts shall not be disconnected, and unused portions of the system shall not be blanked off without means provided to maintain required airflow.

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

9.7.3 Wet-Type Dust Collectors.

9.7.3.1 The exhaust vent shall terminate outside the building and shall be fastened securely.

9.7.3.2* 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.

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

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

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

9.7.3.6* The dust collector shall be arranged so that the dust-laden airstream is thoroughly scrubbed by the liquid to achieve the desired efficiency.

9.7.3.7 Collector Sump Venting.

9.7.3.7.1 The sump of water wet-type dust collectors shall be ventilated at all times.

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

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

9.7.3.8 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 activate visual and audible alarms at the equipment it serves and at an area that is occupied at all times that the equipment is in operation.

9.7.3.9 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the collector is in complete operation.

9.7.4* Dry-Type Dust Collectors.

9.7.4.1 Electrostatic and media collectors shall not be used.

9.7.4.2 Dry-type cyclone dust collectors shall be located outside of buildings.

9.7.4.3 Design.

9.7.4.3.1 Dry-dust collection systems shall be designed and maintained so that internal cleanliness is ensured.

9.7.4.3.2 The accumulation of material inside any area of the collector other than in the discharge containers designed for that purpose shall not be permitted.

9.7.4.4 Accumulation or condensation of water at any point in the dry-dust collection system shall be prevented.

9.7.4.5 Dust shall be removed from the dry collectors at the end of each workday, and at more frequent intervals if conditions warrant.

(A) Extreme care shall be taken in removing dust from the collectors to avoid creating dust clouds.

(B) The dust shall be discharged into properly bonded and grounded metal containers that shall be promptly covered to avoid the creation of airborne fugitive dust.

9.7.4.6* The cyclone dust collector shall be of suitable conductive metal construction for the service intended.

9.7.4.7 Repairs.

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

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

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

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

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

9.7.5 Recycling of Exhaust Air. Recycling of air from dry dust collectors into buildings shall be prohibited.

9.8 In-Plant Conveying of Tantalum Powder.

9.8.1 Enclosed Mechanical Conveyors.

9.8.1.1 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.

9.8.1.2 Coverings on clean-out, inspection, and other openings shall be closed and fastened.

9.8.1.3* 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 9.4.5.

9.8.1.4 Power Shutoff.

9.8.1.4.1 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.

9.8.1.4.2 Feed to the conveyor shall be stopped or diverted.

9.8.2 Pneumatic Conveying.

9.8.2.1 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.*

9.8.2.2 Power Shutoff.

9.8.2.2.1 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.

9.8.2.2.2 Feed to the conveyor shall be stopped or diverted.

9.8.2.3* The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

9.8.3 Ductwork for Conveying Systems.

9.8.3.1 Nonconductive duct or duct liners shall not be used.

9.8.3.2 Ducts shall be electrically bonded and grounded.

9.8.3.3* Deflagration venting (e.g., rupture diaphragms) shall be provided on ductwork.

9.8.3.3.1 Deflagration vents shall relieve to a location outside of the building.

9.8.3.3.2* The design of deflagration venting shall be in accordance with good engineering practice.

9.8.3.4 Wherever damage to other property or injury to personnel can result from the rupture of the ductwork, and where explosion-relief vents cannot provide pressure relief, the ductwork shall be designed to withstand a sudden internal gauge pressure of 862 kPa (125 psi).

9.8.3.5 Ductwork located such that no damage to property or injury to personnel can result from its bursting shall be permitted to be of light construction so as to intentionally fail, thereby acting as an auxiliary explosion vent for the system.

9.8.4 Fan Construction and Arrangement.

9.8.4.1 Fans shall be installed in accordance with the air-moving device requirements of NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

9.8.4.2 Blades and housings of fans used to move air, argon, or helium in conveying ducts shall be constructed of conductive, nonsparking metal, such as bronze, nonmagnetic stainless steel, or aluminum.

9.8.4.3 Fan motors shall be located outside the duct airstream.

9.9 General Storage of Tantalum.

9.9.1 Storage with Incompatible Materials. Tantalum shall not be stored in an area with incompatible materials.

9.9.2 Scrap Storage.

9.9.2.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

9.9.2.2 Storage of scrap, chips, fines, and dust that are ignitable shall be isolated and segregated from other combustible materials to prevent propagation of a fire.

9.9.3 Powder Storage.

9.9.3.1* Tantalum powder shall be stored in covered containers.

9.9.3.2 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.

9.9.3.3 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).

9.9.3.4 Stacked storage shall be arranged to ensure stability.

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

9.9.4 Other Production Materials.

9.9.4.1 Magnesium Operations. All magnesium storage, handling, and processing operations in tantalum production operations shall be in accordance with the requirements of Chapter 6.

9.9.4.2 Sodium Operations. All sodium storage, handling, and processing operations shall be in accordance with Chapter 10.

9.9.4.3 Flammable and Combustible Liquids. Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

9.10 Fire Prevention and Fire Protection. The provisions of Section 9.10 shall apply to all new and existing tantalum powder production processes, handling, and storage operations.

9.10.1 Hot Work.

9.10.1.1* No open flames, electric or gas cutting or welding, or other spark-producing operations shall be permitted in the section of the building where tantalum is present, unless approved hot-work procedures are followed by qualified personnel.

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

9.10.1.3 All hot-work areas that require a permit shall have exposed tantalum chips, turnings, powder, or compacted tantalum powders removed or protected before hot work is performed.

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

9.10.3 Housekeeping. Fugitive tantalum dust shall not be allowed to accumulate. *(See A.6.4.2.1.)*

9.10.3.1 Inspections.

9.10.3.1.1 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.

9.10.3.1.2 Records of the inspections specified in 9.10.3.1.1 shall be kept.

9.10.3.2* Systematic cleaning of the specific section of the building containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as conditions warrant.

(A) The cleaning shall include machinery.

(B) 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 tantalum dust.

(C) Chips or powder shall be removed to a designated storage or disposal area.

9.10.3.3* Bulk accumulations of fine tantalum shall be removed by natural-fiber push brooms and nonsparking scoops or shovels before vacuum cleaning equipment is used.

9.10.3.3.1 Cleanup of the bulk of spilled powder shall be accomplished using conductive, nonsparking scoops and brooms or brushes that have natural-fiber bristles.

9.10.3.3.2 Vacuum cleaning, using vacuum cleaning systems designed and approved for handling combustible metals, shall be permitted only for small amounts of residue material remaining after preliminary cleanup.

9.10.3.4 Due to the inherent hazards associated with the use of vacuum cleaning systems and portable vacuum systems for finely divided tantalum dust, special engineering analysis shall be given to the design, installation, maintenance, and use of such systems.

9.10.3.5* The use of vacuum sweeping devices shall be permitted for cleaning.

(A) If vacuum apparatus is used, both stationary and portable types shall be grounded and bonded and checked for electrical continuity from pickup nozzle to piping system.

(B) Vacuum sweeping devices, if electrical, shall be of a class approved for use in atmospheres containing tantalum dust. *(See 9.1.3.1.)*

(C) Blowing down of any surfaces by compressed air shall be prohibited.

9.10.4 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in tantalum-processing areas.

9.10.5 Where ordinary combustible materials are necessary for the process and are stored in designated areas, 9.10.4 shall not apply.

9.10.6 Ordinary combustible materials shall not be discarded in containers used for the collection of chips or powder.

9.10.7 Floor sweepings from tantalum operations shall be permitted to contain small amounts of ordinary combustible materials and shall be stored in separate containers.

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

9.10.9 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.

Chapter 10 Titanium

10.1 Sponge Production.

10.1.1 Plant Construction.

10.1.1.1 Buildings housing reduction furnaces, boring and crushing facilities, and titanium refining operations shall be constructed of noncombustible materials.

10.1.1.2* Consideration shall be given to the provision of explosion venting in accordance with current accepted practices.

10.1.1.3 Building exits shall comply with NFPA *101*, *Life Safety Code*.

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

10.1.1.5 Titanium winning, refining, and casting operations shall be protected from rain and from other possibilities of inadvertent contact with water.

10.1.1.6 Permanent water lines in the winning, refining, and casting operations area shall be of all-metal construction.

10.1.1.7 Hose used for cleaning and washdown purposes shall be pressurized only while in active use for cleaning and washdown operations.

10.1.2 Processing Equipment.

10.1.2.1 Reactor vessels shall be air cooled.

10.1.2.2 Sealed titanium-reduction vessels shall be permitted to be water cooled and shall be designed to prevent water from entering the reaction vessel.

10.1.2.3 Furnaces shall be kept dry and free of iron scale and metal spillage.

10.1.2.4* Fuel supply lines to gas-fired furnaces shall have an emergency shutoff valve located within easy access outside of the building that contains the reduction furnaces.

10.1.2.5 All electrically operated or controlled processing equipment shall be installed in accordance with *NFPA 70, National Electrical Code*.

10.1.3 Storage of Raw Materials.

10.1.3.1 Magnesium ingots for use in the Kroll process shall be stored in accordance with Chapter 6.

10.1.3.2* Chlorine shall be handled and stored in accordance with accepted industry practice.

10.1.3.3* 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.

10.1.4 Dust Collection.

10.1.4.1 Dust resulting from the crushing of titanium sponge shall be managed safely to minimize the risk of fires and explosions.

10.1.4.2 Media collectors shall not be used for the collection of titanium sponge fines.

10.1.4.3* Dust collectors for Kroll-distilled material shall be located outside of buildings and shall be provided with explosion vents.

10.1.4.4* Fans that handle combustible dust and air mixtures shall be constructed of nonsparking materials and shall be constructed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*.

10.1.5* Personnel Safety Precautions. Personnel involved in reduction-furnace tapping, removal of molten titanium chloride, and titanium refining and casting shall wear tight-fitting, above-the-ankle shoes, flame-retardant clothing, heat-resistant gloves, and face shields.

10.1.6 Sponge Storage.

10.1.6.1 Titanium sponge shall be stored in closed metal containers.

(A) The maximum weight of material shall be capable of being moved by the available equipment.

(B) Containers shall not be airtight.

10.1.6.2 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 10.7, and shall be plainly marked with "No Smoking" signs.

10.1.6.3 Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of not more than four pallet loads.

10.1.6.4 Stacked storage shall be positioned in such a manner as to ensure stability.

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

10.2 Titanium Melting.

10.2.1* Explosion Prevention.

10.2.1.1 Water Supply.

10.2.1.1.1 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 waterflow.

10.2.1.1.2 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.

10.2.1.2 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.

10.2.1.3* 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.

(A) Means shall be provided to prevent the influx of air through the pressure-relief port.

(B) The release pressure of the rupture disc shall be at a gauge pressure of 138 kPa (20 psi) maximum.

(C) Large low-pressure ports shall not be used.

10.2.1.4 A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

10.2.1.5 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

10.2.1.6 Pressure-Sensing Device.

10.2.1.6.1 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

10.2.1.6.2 The device shall automatically interrupt power to the melting heat source in the event of an expected sharp rise in pressure.

10.2.1.7 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 all systems to warn of abnormal conditions

10.2.2* Casting.

10.2.2.1* Water Supply.

10.2.2.1.1 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.

10.2.2.1.2 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.

10.2.2.2 Molds.

10.2.2.2.1 Molds for titanium casting shall be made of material that is compatible with molten titanium.

10.2.2.2.2 Molds shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

10.2.2.3 The casting chamber shall be cooled or shall be sufficiently massive to accommodate a spill, or both, since mold breaks are inevitable.

10.2.2.4 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside furnace vaults.

10.2.2.5* Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

10.3 Mill Operations.

10.3.1* Scope. Mill operations shall cover the forging and finishing of titanium products in a primary production facility.

10.3.2 Fire Prevention.

10.3.2.1 Tanks in which flammable or combustible solvents are used for degreasing shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

10.3.2.2* Sawing, grinding, polishing, buffing, and cutting equipment shall be grounded.

10.3.2.3 Furnaces or other heating equipment used for heating titanium shall be free of iron scale or residue that could react exothermically with the metal being heated.

10.4 Machining, Fabrication, and Finishing of Parts.

10.4.1 Scope.

10.4.1.1 Section 10.4 shall apply to operations where titanium is subjected to processing or finishing operations.

10.4.1.2 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.

10.4.2 Machining Operations.

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

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

10.4.3 Welding.

10.4.3.1 All welding of titanium shall be carried out under an inert atmosphere, such as helium or argon, or under vacuum.

10.4.3.2 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, and dust are produced, handled, packaged, or stored.

10.4.4 Titanium Dust Collection.

10.4.4.1 Hoods or Enclosures.

10.4.4.1.1 Titanium dust shall be collected by means of hoods or enclosures at each dust-producing operation.

10.4.4.1.2* The hoods or enclosures shall be connected to liquid precipitation separators, and the suction unit shall be installed so that the dust is converted to sludge without contact, in the dry state, with any high-speed moving parts.

10.4.4.2 Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded.

10.4.4.2.1 Ducts and tubes shall be as short as possible, with no unnecessary bends.

10.4.4.2.2 Ducts shall be fabricated and installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*.

10.4.4.3 Titanium dust–producing equipment shall be connected to dust-collecting equipment.

10.4.4.3.1 Multiple pieces of titanium dust–producing equipment shall be permitted to be connected to a single titanium dust–collecting unit.

10.4.4.3.2 An evaluation shall be made to determine whether multiple pieces of dust-producing equipment can be served safely by a single dust-collecting unit.

10.4.4.4* If the titanium dust–collecting unit is to be used for other materials, it shall be thoroughly cleaned of all incompatible materials prior to and after use.

10.4.4.5 Grinders, buffers, and associated equipment with dust collectors utilized for processing titanium shall be provided with a placard that reads as follows:

CAUTION:

Current Use: Titanium Metal —

Fire or Explosion Can Result with Other Metals

10.4.4.6 Power Supply.

10.4.4.6.1 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.

10.4.4.6.2 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the collector is in complete operation.

10.4.4.7 Sludge from dust collectors and vacuum cleaning system precipitators shall be removed daily as a minimum.

10.4.4.7.1 Covered, vented steel containers shall be used to transport collected sludge to a safe storage area or for disposal.

10.4.4.7.2 Sludge shall be disposed of in accordance with federal, state, and local regulations.

10.4.5 Dust-Producing Operations.

10.4.5.1 Machines that produce fine particles of titanium 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.

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

10.4.5.1.2 Dust shall be collected by means of hoods or enclosures at each operation.

10.4.5.2* 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 as possible.

10.4.5.3 Machining Coolant.

10.4.5.3.1 Noncombustible coolants shall be used for wet grinding, cutting, and sawing operations.

10.4.5.3.2 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.

10.4.6 Dust Collection Ducts and Ductwork.

10.4.6.1 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.*

10.4.6.2 Ducts shall be designed to maintain a velocity of not less than 1365 m/min (4500 ft/min) to ensure the transport of both coarse and fine particles and to ensure re-entrainment if, for any reason, the particles fall out before delivery to the collector (e.g., in the event of power failure).

10.4.6.3 Ducts shall be designed to handle a volumetric flow rate that maintains dust loads safely below the MEC.

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

10.4.6.5 Duct Construction.

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

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

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

10.4.6.5.4 Additional branch ducts shall not be added to an existing system without redesign of the system.

10.4.6.5.5 Branch ducts shall not be disconnected, and unused portions of the system shall not be blanked off without providing means to maintain required airflow.

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

10.4.7 Wet-Type Dust Collectors.

10.4.7.1 The exhaust vent shall terminate outside the building and shall be fastened securely.

10.4.7.1.1 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.

10.4.7.1.2 The cleaned 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 with regard to particulate matter in the cleaned air and to accumulations of particulate matter in the work area.

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

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

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

10.4.7.5 The dust collector shall be arranged so that the dust-laden airstream is thoroughly scrubbed by the liquid to achieve the desired efficiency.

10.4.7.6 Collector Sump Venting.

10.4.7.6.1 The sump of water wet-type dust collectors shall be ventilated at all times.

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

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

10.4.7.7 Power Supply.

10.4.7.7.1 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.

10.4.7.7.2 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the collector is in complete operation.

10.4.8 Dry-Type Dust Collectors.

10.4.8.1 Electrostatic and media collectors shall not be used.

10.4.8.2 Dry-type cyclone dust collectors shall be located outside of buildings.

10.4.8.3 Dry dust collection systems shall be designed and maintained so that internal cleanliness is ensured.

10.4.8.4 The accumulation of material inside any area of the collector other than in the discharge containers designed for that purpose shall not be permitted.

10.4.8.5 Accumulation or condensation of water at any point in the dry dust collection system shall be prevented.

10.4.8.6 Dust shall be removed from the dry collectors at the end of each workday and at more frequent intervals if conditions warrant.

10.4.8.6.1 Extreme care shall be taken in removing dust from the collectors to avoid creating dust clouds.

10.4.8.6.2 The dust shall be discharged into properly bonded and grounded metal containers that shall be covered promptly to avoid the creation of airborne fugitive dust.

10.4.8.6.3 Dry collectors shall be emptied before or when 100 percent of the storage capacity of the collector is attained.

10.4.8.6.4 The maximum volume of titanium fines collected before emptying shall not exceed 19 L (5 gal).

10.4.8.7* The cyclone dust collector shall be of conductive metal construction suitable for the service intended.

10.4.8.7.1 The cyclone dust collector shall be solid welded with smooth internal seams.

10.4.8.7.2 The equipment shall be provided with a sparkproof air lock on the hopper discharge and connected to a covered material receiver.

10.4.8.7.3 Exhaust fans used in conjunction with the equipment shall be installed on the clean-air side of the system and shall be of sparkproof construction.

10.4.8.7.4 Motors and controls of any type associated with the process airstream shall be located outside the process airstream.

10.4.8.7.5 All equipment shall be bonded and grounded.

10.4.8.8 Repairs.

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

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

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

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

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

10.4.9 Recycling of Exhaust Air. Recycling of air from dry dust collectors into buildings shall be prohibited.

10.5 Scrap Storage.

10.5.1* Storage.

10.5.1.1 Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

10.5.1.2 Storage of materials in closed noncombustible containers shall be permitted.

10.6 Titanium Powder Production and Use.

10.6.1* Drying and Storage of Titanium Powder.

10.6.1.1 Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

10.6.1.2* Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*.

(A) Drying rooms shall be segregated as far as possible from other operations and at no time less than 15.2 m (50 ft).

(B) An analysis shall be performed to determine whether drying rooms require deflagration venting.

10.6.1.3 Titanium powder shall be stored in sealed containers in well-ventilated areas.

(A) The containers shall be kept free of combustibles.

(B) The containers shall be protected from damage.

10.6.2 Titanium Powder Handling.

10.6.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

10.6.2.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

10.6.2.2.1 Hot zones of furnaces that handle titanium in any form shall be provided with inert atmospheres or vacuum.

10.6.2.2.2* The furnaces shall be designed in accordance with good engineering practice.

10.6.2.3* 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.

10.6.2.4* Electrical Installations. In local areas of a plant where a hazardous quantity of 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*.

10.6.3 Personnel Safety Precautions. Personnel handling dry titanium powder shall wear nonsparking shoes and noncombustible or flame-retardant clothing without pockets, cuffs, laps, or pleats in which powder can accumulate.

10.7 Fire Prevention and Fire Protection. The provisions of Section 10.7 shall apply to all new and existing titanium production, processing, handling, and storage operations.

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

10.7.2 Sponge Collection.

10.7.2.1 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than 1814 kg (4000 lb).

10.7.2.2 The collection area shall be well ventilated and free from other combustible material.

10.7.3* Molten Titanium.

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

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

10.7.4 Housekeeping.

10.7.4.1 Systematic cleaning of the entire building containing dust-producing equipment, including roof members, pipes, conduits, and so on, shall be conducted as conditions warrant.

10.7.4.2 Cleaning methods shall be limited to those methods that minimize the probability of causing a fire or explosion, as determined by a person knowledgeable in the properties of titanium dust.

10.7.4.3 Due to the inherent hazards associated with the use of fixed vacuum cleaning systems for finely divided titanium dust, special engineering considerations shall be given to the design, installation, maintenance, and use of such systems.

10.7.4.4 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.

10.7.5 Regular, periodic cleaning of titanium dust and fines from buildings and machinery shall be carried out as frequently as conditions warrant.

(A) Dust and fines shall be removed to a safe storage or disposal area.

(B) 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.

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

10.7.6 Inspections.

10.7.6.1 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.

10.7.6.2 Records shall be kept of the inspections specified in 10.7.6.1.

10.7.7 Oil spills shall be cleaned up immediately.

10.7.8 All electrical equipment and wiring in titanium production, processing, handling, and storage facilities shall comply with *NFPA 70*, *National Electrical Code*.

10.7.9 Only nonsparking tools and utensils shall be used in handling titanium powder.

10.7.10* All metal objects or equipment used to process titanium shall be electrically bonded and grounded to prevent accumulations of static electricity.

10.7.11 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.

Chapter 11 Zirconium

11.1 Sponge Production.

11.1.1 Magnesium Operations. All magnesium storage, handling, and processing operations in zirconium sponge production operations shall be in accordance with the requirements of Chapter 6.

11.1.2 Plant Construction.

11.1.2.1 Buildings that house reduction furnaces, boring and crushing facilities, and magnesium refining operations shall be constructed of noncombustible materials.

11.1.2.2* Consideration shall be given to the provision of deflagration venting in accordance with current accepted practices.

11.1.2.3 Building exits shall comply with NFPA *101*, *Life Safety Code*.

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

11.1.2.5 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.

11.1.3 Processing Equipment.

11.1.3.1 Chlorinators and reduction vessels shall be designed and maintained to prevent water from entering the reaction chamber.

11.1.3.2 Furnaces shall be kept dry and free of iron scale and other foreign material.

11.1.3.3 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*.

11.1.3.4 Furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces*.

11.1.3.5 All electrically operated or controlled processing equipment shall be installed in accordance with *NFPA 70*, *National Electrical Code*.

11.1.3.6 Backup methods or systems shall be provided to allow for the safe and orderly shutdown of critical processes in the case of primary system failure.

11.1.4 Storage of Raw Materials.

11.1.4.1* Chlorine shall be handled and stored in accordance with accepted industry practice.

11.1.4.2 Storage and handling of flammable and combustible liquids shall be in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

11.1.4.3* Bulk Containers.

11.1.4.3.1 Bulk containers of zirconium tetrachloride ($ZrCl_4$) and silicon tetrachloride ($SiCl_4$) shall be stored in a well-ventilated area located away from areas of acute hazard.

11.1.4.3.2 Containers shall be identified plainly and tightly sealed until used.

11.1.5 Dust Collection.

11.1.5.1 Dust resulting from the crushing of zirconium sponge shall be managed safely to minimize the risk of fires and explosions.

11.1.5.2 Media collectors shall not be used for the collection of zirconium sponge fines.

11.1.5.3 Collected Material.

11.1.5.3.1 Non-media-based dry collectors shall be emptied before or when 80 percent of the storage capacity is attained.

11.1.5.3.2 The maximum volume of zirconium fines collected before emptying shall not exceed 19 L (5 gal).

11.1.5.4* Dust collectors for Kroll-distilled material shall be located outside of buildings and shall be provided with deflagration vents.

11.1.5.5* Fans that handle combustible dust and air mixtures shall be constructed of nonsparking materials and in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids.*

11.1.6* Personnel Safety Precautions. Personnel involved in reduction furnace tapping, removal of molten magnesium chloride, and magnesium refining and casting shall wear tight-fitting, above-the-ankle shoes, flame-retardant clothing, heat-resistant gloves, and face shields.

11.1.7 Sponge Storage.

11.1.7.1 Dry zirconium sponge shall be stored in closed metal containers with a maximum capacity that is capable of being moved by available equipment.

11.1.7.2* Wet zirconium sponge shall be stored in nonsealing, covered metal containers with a maximum capacity that is capable of being moved by available equipment.

11.1.7.3 Zirconium 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.

11.1.7.4 Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of not more than four pallet loads.

11.1.7.5 Stacked storage shall be arranged to ensure stability.

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

11.2* Zirconium Melting.

11.2.1 Explosion Prevention.

11.2.1.1 Water Supply.

11.2.1.1.1 The water supply to crucibles shall be continuously monitored by a system that automatically interrupts power to the furnace upon a drop in water pressure or waterflow.

11.2.1.1.2 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.

11.2.1.2 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 if an explosion occurs.

11.2.1.3* 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. The release pressure of the pressure-relieving device shall be a maximum gauge pressure of 138 kPa (20 psi).

11.2.1.4* A clearance shall be maintained at all times between the electrode and the crucible wall to minimize arcing to the crucible wall.

11.2.1.5 Pressure-Sensing Device.

11.2.1.5.1 The furnace shall be equipped with a device that continuously senses pressure within the furnace.

11.2.1.5.2 The device shall automatically interrupt power to the melting heat source in the event of an unexpected sharp rise in pressure.

11.2.1.6 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 all systems to warn of abnormal conditions

11.2.2* Casting.

11.2.2.1 Water Supply.

11.2.2.1.1 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.

11.2.2.1.2 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.

11.2.2.2 Molds.

11.2.2.2.1 Molds for zirconium casting shall be made of material that is compatible with molten zirconium.

11.2.2.2.2 Molds shall be dried thoroughly and stored carefully to prevent accumulation of moisture in the molds.

11.2.2.3 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.

11.2.2.4 Control consoles for water-cooled melting and casting operations shall be located remote from melting areas and outside of furnace enclosures.

11.2.2.5* Residue from casting furnaces shall be placed in steel boxes and moved outside of the building.

11.3* Mill Operations.

11.3.1 Fire Prevention.

11.3.1.1 Flammable or combustible liquids shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

11.3.1.2* All electrically driven equipment used for sawing, cutting, or grinding operations shall be grounded in accordance with *NFPA 70, National Electrical Code*.

11.3.1.3 Zirconium chips shall be collected in covered metal containers and removed daily, as a minimum, to a safe storage or disposal area.

11.3.1.4 Forge presses, heavy grinders, and other milling equipment operated by hydraulic systems shall use a less hazardous hydraulic oil with a flash point greater than 93°C (200°F).

11.3.2 Coolants.

11.3.2.1 Nonflammable coolants shall be used for wet grinding, cutting, and sawing operations.

11.3.2.2 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 moved to a safe storage or disposal area.

11.3.2.3 Flammable or combustible liquid coatings applied to zirconium shall be used in accordance with the requirements of NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*.

11.3.2.4 Oily crushed lathe turnings, raw turnings, and chips shall be collected in covered metal containers and removed daily, as a minimum, to a safe storage or disposal area.

11.3.2.5 Furnaces or other heating equipment used for heating zirconium shall be free of iron scale or residue that could react exothermically with the metal being heated.

11.4 Machining and Fabrication.

11.4.1 Machining Operations.

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

11.4.1.2 Nonflammable coolants or lubricants shall be used to minimize heat generated by the cutting operation.

11.4.2 Welding.

11.4.2.1 All welding of zirconium shall be carried out under a helium or argon atmosphere or under vacuum.

11.4.2.2* Hot work such as electric arc or gas torch welding shall not be permitted in areas where zirconium powder or chips are produced, handled, packaged, or stored until all exposed powder or chips have been removed and exposed equipment has been cleaned thoroughly.

11.4.3 Zirconium Dust Collection.

11.4.3.1 Hoods or Enclosures.

11.4.3.1.1 Zirconium dust shall be collected by means of hoods or enclosures at each dust-producing operation.

11.4.3.1.2* The hoods or enclosures shall be connected to liquid precipitation collectors, and the suction unit shall be installed so that the dust is converted to sludge without making contact, in the dry state, with any high-speed moving parts.

11.4.3.2 Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded.

11.4.3.2.1 Ducts and tubes shall be as short as practicable, with no unnecessary bends.

11.4.3.2.2 Ducts shall be fabricated and installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*.

11.4.3.3 Zirconium dust–producing equipment shall be connected to dust-collecting equipment.

11.4.3.3.1 Multiple pieces of zirconium dust–producing equipment shall be permitted to be connected to a single zirconium dust–collecting unit.

11.4.3.3.2 An evaluation shall be made to determine whether multiple pieces of dust-producing equipment can be safely served by a single dust-collecting unit.

11.4.3.4* If the zirconium dust–collecting unit is to be used for other materials, it shall be thoroughly cleaned of all incompatible materials prior to and after its use.

11.4.3.5 Power Supply.

11.4.3.5.1 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 shuts down the equipment it serves.

11.4.3.5.2 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the collector is in complete operation and several air changes have swept out any residual hydrogen.

11.4.3.6 Housekeeping.

11.4.3.6.1 Systematic cleaning of the entire building containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as conditions warrant.

11.4.3.6.2 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 zirconium dust.

11.4.3.6.3 Due to the inherent hazards associated with the use of vacuum cleaning systems for finely divided zirconium dust, special engineering considerations shall be given to the design, installation, maintenance, and use of such systems.

11.4.3.7* Sludge from dust collectors and vacuum cleaning system precipitators shall be removed daily, as a minimum, and shall be kept thoroughly wet.

11.4.3.7.1 Nonsealing, covered metal containers shall be used to transport collected sludge to a safe storage area or for disposal.

11.4.3.7.2 Sludge shall be disposed of in accordance with federal, state, and local regulations.

11.5* Scrap Storage.

11.5.1 Open storage of sheet, plate, forgings, or massive pieces of scrap shall be permitted.

11.5.2 Storage of sponge, chips, fines, and dust that are readily ignitable shall be isolated and segregated from other combustible materials and zirconium scrap to prevent propagation of a fire.

11.6* Zirconium Powder Production and Use.

11.6.1 Drying and Storage of Zirconium Powder.

11.6.1.1* Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

11.6.1.2* Drying rooms shall be of Type I construction, as defined by NFPA 220, *Standard on Types of Building Construction*.

(A) Drying rooms shall be segregated as far as practicable from other operations.

(B) An analysis shall be performed to determine whether drying rooms require deflagration venting.

11.6.1.3 Zirconium powder shall be stored in sealed containers in well-ventilated areas.

(A) The containers shall be kept segregated from other combustibles.

(B) The containers shall be protected from damage.

11.6.2 Zirconium Powder Handling.

11.6.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

11.6.2.2* Sintering furnaces that handle zirconium parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86, *Standard for Ovens and Furnaces*.

(A) Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

(B) Furnaces shall be operated with inert atmospheres of helium or argon or under vacuum.

11.6.2.3 To minimize the risk of fire or explosion hazard in the handling of zirconium powder, the equipment and processes shall be designed by persons knowledgeable in the hazards of zirconium powder.

11.6.2.4 Electrical Installations.

11.6.2.4.1 All zirconium powder production, drying, and packing areas shall be evaluated for fire and explosion hazards associated with the operation and shall be provided with approved electrical equipment for the hazardous location.

11.6.2.4.2* In local areas of a plant where a hazardous quantity of 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*.

11.6.3 Personnel Safety Precautions. Personnel handling zirconium powder shall wear nonsparking shoes and noncombustible or flame-retardant clothing that is designed to minimize the accumulation of zirconium powder.

11.6.4 Housekeeping Practices.

11.6.4.1 Good housekeeping practices shall be followed so that accumulations of powder are minimized.

11.6.4.2 Special attention shall be paid to powder accumulations in crevices and joints between walls and floors.

11.7 Fire Prevention and Fire Protection. The provisions of Section 11.7 shall apply to all new and existing zirconium production processing, handling, and storage operations.

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

11.7.2 Sponge Collection.

11.7.2.1 Sponge discharged from dryers shall be collected in containers with a maximum capacity of 1814 kg (4000 lb).

11.7.2.2 The collection area shall be well ventilated and free from other combustible materials.

11.7.3* Other Molten Materials.

11.7.3.1 All containers used to receive molten metal, molten magnesium, molten magnesium chloride, or liquid sodium shall be cleaned and dried thoroughly before use.

11.7.3.2 All pieces of magnesium metal shall be clean and dry where charged to reduction furnaces.

11.7.4 Good housekeeping practices shall be maintained.

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

11.7.4.2 Supplies of materials in zirconium processing areas shall be limited to the amounts necessary for normal operation.

11.7.5* Periodic Cleaning.

11.7.5.1 Periodic cleaning of zirconium sponge, chips, or powder from buildings and machinery shall be carried out as frequently as conditions warrant.

11.7.5.2 Sponge, chips, or powder shall be removed to a safe storage or disposal area.

11.7.6 Periodic Inspections.

11.7.6.1 Periodic inspections shall be conducted, as frequently as conditions warrant, to detect the accumulation of excessive zirconium sponge, chips, or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

11.7.6.2 Records shall be kept of the inspections specified in 11.7.6.1.

11.7.7* Disposal of Ordinary Combustible Materials.

11.7.7.1 Ordinary combustible materials shall not be discarded in containers used for the collection of sponge, chips, or powder.

11.7.7.2 Floor sweepings from zirconium operations shall be permitted to contain small amounts of ordinary combustible materials.

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

11.7.9 Smoking shall not be permitted in areas where ignitable zirconium sponge, chips, or powder is present.

11.7.9.1 Areas where zirconium sponge, chips, or powder is present shall be posted with "No Smoking" signs.

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

11.7.10 All electrical equipment and wiring in zirconium production, processing, handling, and storage facilities shall comply with *NFPA 70, National Electrical Code*.

11.7.11 Where tools and utensils are used in areas handling zirconium powder, consideration shall be given to the risks associated with generating impact sparks and static electricity.

11.7.12* Processing equipment used in zirconium operations shall be electrically bonded and grounded properly in order to prevent accumulations of static electricity.

11.7.13 Where zirconium 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.

Chapter 12 Requirements for Combustible Metals Not Covered in Chapter 5 through Chapter 11

12.1 Building Construction.

12.1.1 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.

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

12.1.3 Building areas where combustible metal dusts might be present shall be designed so that all internal surfaces are accessible, to facilitate cleaning.

12.1.3.1 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.

12.1.3.2 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

12.1.3.3 Roofs.

12.1.3.3.1 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.

12.1.3.3.2 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.

12.1.3.4 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.

12.1.4 Roof decks and basements shall be watertight.

12.1.5* Explosion venting is 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.

12.1.6 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*.

12.1.7 Enclosed Passageways.

12.1.7.1* 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.

12.1.7.2 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*.

12.1.8 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.

12.1.9 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.

12.2 Manufacturing and Processing.

12.2.1 Dust-Producing Operations.

12.2.1.1* Machines that produce fine particles of 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. 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. Dust shall be collected by means of hoods or enclosures at each operation.

12.2.1.2* 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.

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

12.2.1.4 Dry-type dust collectors shall be located outside of buildings.

12.2.1.4.1* Individual machines with portable dust collection capability shall be permitted to be used indoors when the object being processed or finished is incapable of being moved to a fixed hood or enclosure.

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

12.2.1.4.3 Personnel protective clothing shall comply with 12.2.4.16.

12.2.1.4.4 The collector shall be designed to dissipate static electricity.

12.2.1.4.5 Collector retention capacity shall be limited to 0.45 kg (1 lb).

12.2.1.5* Dry-type collectors shall be provided with barriers or other means for protection of personnel.

12.2.1.6* The area around the collector shall be posted with a sign that reads as follows:

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

12.2.1.7* If the metal dust–collecting unit is to be used for other materials, it shall be thoroughly cleaned of all incompatible materials prior to and after use.

12.2.1.8 Grinders, buffers, and associated equipment with dust collectors utilized for processing metal dust shall be provided with a placard that reads as follows:

CAUTION:

Current Use: [Type of Metal] —

Fire or Explosion Can Result with Other Metals

12.2.1.9* Cutting tools shall be designed for use with the metal being worked and shall be kept sharp.

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

12.2.1.11 All metal chips, oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top containers and removed daily, at a minimum, to a designated storage or disposal area.

12.2.1.12 Nonflammable coolants shall be used for wet grinding, cutting, and sawing operations.

12.2.1.12.1 The coolant shall be filtered on a continuous basis.

12.2.1.12.2 The collected solids shall not be allowed to accumulate in quantities greater than 19 L (5 gal) and shall be removed to a designated storage or disposal area.

12.2.2 Powder Handling and Use.

12.2.2.1 Where metal powder or paste is used or handled, good housekeeping practices shall be maintained.

12.2.2.2 Metal powder and paste shall be handled so as to avoid spillage and the creation of airborne dust.

12.2.2.3 Scoops, shovels, and scrapers used in the handling of metal powder and paste, in atmospheres other than inert atmospheres, shall be electrically conductive and shall be bonded and grounded, and hand tools shall be made of spark-resistant materials.

12.2.2.4 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 12.5.2.

12.2.2.5 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 medium in the collector.

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

12.2.3* Transfer Operations. Operations involving the transfer of combustible metal dusts or powders from one container to another shall be designed and operated to protect personnel, equipment, or buildings from the fire or dust explosion hazard produced by airborne suspensions of combustible metal dusts or powders.

12.2.3.1 Precautions shall be taken to prevent spills or dispersions that produce dust clouds.

12.2.3.2 Special temperature controls shall be required on sintering furnaces that handle metal parts that are fabricated from powder.

(A) Powder or dust shall not be permitted to accumulate in the furnace or near the heating elements.

(B) Furnaces shall be provided with inert atmospheres.

12.2.3.3* To minimize the risk of fire or explosion hazards in the handling of dry metal powders, the equipment and processes shall be designed by persons knowledgeable in the hazards of metal powders.

12.2.4 Melting and Casting Operations.

12.2.4.1* Water-cooled vacuum arc furnaces shall be designed with safety interlock systems that will allow the furnace to operate only if there is sufficient cooling waterflow to prevent overtemperature of the melting crucible.

12.2.4.2 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.

12.2.4.3 Buildings used for the melting and casting of metals shall be noncombustible.

12.2.4.4 Floors shall be kept free of standing water.

12.2.4.5* All solid metal shall be thoroughly dried throughout by preheating or other methods prior to coming into contact with molten metal.

12.2.4.6 Ovens and furnaces shall comply with NFPA 86, *Standard for Ovens and Furnaces.*

12.2.4.7 Fuel supply lines shall comply with NFPA 54, *National Fuel Gas Code.*

12.2.4.8 Use of flammable and combustible liquids shall comply with NFPA 30, *Flammable and Combustible Liquids Code.*

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

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

12.2.4.11 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.

12.2.4.12 Pots and Crucibles.

12.2.4.12.1 Melting pots and crucibles shall be inspected regularly.

12.2.4.12.2 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.

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

12.2.4.14 Extreme care shall be exercised in pouring metal castings, to avoid spillage.

12.2.4.15 All molds shall be thoroughly preheated before pouring.

12.2.4.16 Operators' Clothing.

12.2.4.16.1 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 foundry shoes, and face protection.

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

12.2.5 Combustible Dust Collection.

12.2.5.1 A documented risk evaluation acceptable to the authority having jurisdiction shall be conducted to determine the level of explosion protection to be provided for a dust collection system.

12.2.5.2 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.*

12.2.5.3 Ducts shall be designed to maintain a velocity that ensures the transport of both coarse and fine particles and to ensure re-entrainment if, for any reason, the particles fall out before delivery to the collector (e.g., in the event of a power failure).

12.2.5.4* Ducts shall be designed to handle a volumetric flow rate that maintains dust loads safely below the MEC.

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

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

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

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

12.2.5.9 Branch Ducts.

12.2.5.9.1 Additional branch ducts shall not be added to an existing system without redesign of the system.

12.2.5.9.2 Branch ducts shall not be disconnected, and unused portions of the system shall not be blanked off without means provided to maintain required airflow.

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

12.2.6 Combustible Metal Wet-Type Dust Collectors.

12.2.6.1 Exhaust Vent.

12.2.6.1.1 The exhaust vent shall terminate outside the building and be securely fastened.

12.2.6.1.2 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.

12.2.6.2 Cleaned 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 or hydrogen in the work area.

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

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

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

12.2.6.6* The dust collector shall be arranged so that the dust-laden airstream is thoroughly scrubbed by the liquid to achieve the desired efficiency.

12.2.6.7 The use of additional dry filter medium, either downstream or combined with a wet collector, shall not be permitted.

12.2.6.8* Sludge shall be removed from the collector on a regular schedule.

12.2.6.9 Removed sludge shall be stored in a covered, vented metal container.

12.2.7 Collector Sump Venting.

12.2.7.1* The sump of water wet-type dust collectors shall be ventilated from the top of the collector at all times.

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

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

12.2.8 Power Supply.

12.2.8.1 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.

12.2.8.2 A time delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the collector is in complete operation.

12.2.9 Disposal of Sludge from Water Wet-Type Dust Collectors.

12.2.9.1 Containers used to transport the collected sludge shall be removed from the process area on at least a daily basis to a designated area for disposal or processing.

12.2.9.2 Sludge shall be permitted to be mixed with inert materials in a ratio of at least five parts inert material to one part sludge and then shall be recycled or discarded in accordance with local, state, and federal requirements.

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

12.2.10 Combustible Metal Dry-Type Dust Collectors.

12.2.10.1 Electrostatic and media collectors shall not be used.

12.2.10.2* Dry-type dust collectors shall be fabricated of conductive material and grounded and bonded.

12.2.10.3 Dry dust collection systems shall be designed and maintained so that internal cleanliness is ensured.

12.2.10.4 The accumulation of material inside any area of the collector other than in the discharge containers designed for that purpose shall not be permitted.

12.2.10.5 Accumulation or condensation of water at any point in the dry dust collection system shall be prevented.

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

(A) Precautions shall be taken in removing dust from the collectors to avoid creating dust clouds.

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

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

12.2.10.7* Dry collectors used for combustible metal dust shall be provided with deflagration vents.

12.2.10.8 The selection of the type and location of the collector shall be designed to minimize injury to personnel and to minimize blast and fire damage to nearby equipment or structures.

12.2.10.9 Repairs.

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

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

12.2.10.10 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.

12.2.10.11 The dust collector shall be arranged so that contact between dust particles and parts moving at high speeds shall be prevented.

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

12.2.11 Recycling of Exhaust Air. Recycling of air from dry dust collectors into buildings shall be prohibited.

12.2.12 Heating and Cooling of Powder Production Buildings.

12.2.12.1 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.

12.2.12.2 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.

12.2.12.3 Fans or blowers used to convey the heated or cooled air shall be located in a combustible metal dust–free location.

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

12.2.12.5 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.

12.2.12.6 The requirements of 12.2.12.1 through 12.2.12.5 shall not apply to areas where metal is melted.

12.2.13 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.

12.2.14 Water leakage inside or into any building where the water can contact metal powder shall be prevented to avoid possible water–metal reactions.

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

12.3 Storage.

12.3.1 Storage of Combustible Scrap Metal.

12.3.1.1 Subsection 12.3.1 shall apply to the storage of scrap metal in the form of solids, chips, turnings, swarf, or other fine particles.

12.3.1.2 Buildings used for the indoor storage of metal scrap shall be of noncombustible construction.

12.3.1.3 Scraps shall be kept well separated from other combustible materials.

(A) Scraps shall be kept in covered steel or other noncombustible containers and shall be kept in such manner or locations that they will not become wet.

(B) Outside storage of metal fines shall be permitted if such storage is separated from buildings or personnel and precautions are exercised to prevent the fines from becoming wet.

12.3.1.4* Wet metal scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location.

(A) Sources of ignition shall be kept away from the container vent and top.

(B) Containers shall not be stacked.

12.3.1.5 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).

12.3.1.6 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.

12.3.1.7 Solid metal scrap, such as clippings and castings, shall be stored in noncombustible bins or containers.

12.3.1.8 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid metal scrap.

12.3.1.9 The use of automatic sprinklers in metal-scrap storage buildings or areas shall be prohibited.

12.3.2 Storage of Combustible Metal Powder.

12.3.2.1 Buildings used to store metal powder shall be of noncombustible construction.

12.3.2.2 The use of automatic sprinklers in metal powder storage buildings shall be prohibited.

12.3.2.3 Metal powder shall be kept separated from other ordinary combustibles or incompatible materials.

12.3.2.4 Metal powder shall be stored in closed steel drums or other closed noncombustible containers.

12.3.2.5 Metal-powder storage areas shall be kept dry and checked for water leakage.

12.3.2.6* In local areas of a plant where a hazardous quantity of 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*.

12.3.2.7* Where metal powder in drums is stacked for storage, the maximum height shall not exceed 3.7 m (12 ft).

(A) Storage drums shall be stacked in a manner that ensures stability.

(B) Under no circumstances shall containers be allowed to topple over.

12.3.3* Storage of Other Metal Products.

12.3.3.1 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.

12.3.3.2 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).

12.3.3.3* 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

12.4 Housekeeping.

12.4.1 Cleanup of Spilled Metal Powder. Preliminary cleanup of the powder shall be accomplished by using conductive, nonsparking scoops and soft brooms, as well as brushes that have natural-fiber bristles.

12.4.2 Cleanup Procedures for Fugitive Dust Accumulations.

12.4.2.1* Fugitive dust shall not be allowed to accumulate.

12.4.2.2 Periodic cleanup of fugitive dusts shall be accomplished by using conductive, nonsparking scoops and soft brooms or brushes that have natural-fiber bristles.

12.4.3* Vacuum Cleaning.

12.4.3.1 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.

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

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

12.4.3.4* Portable vacuum cleaners shall be used only if listed or approved for use with combustible metal dust.

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

12.4.3.5.1 Assembled components shall be conductive and bonded where necessary.

12.4.3.5.2 Periodic tests for continuity shall be performed.

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

12.4.4 Compressed-Air Cleaning Requirements. Compressed-air blowdown shall not be permitted, unless the conditions of 12.4.5 are met.

12.4.5 In certain areas that are otherwise impossible to clean, compressed-air blowdown shall be permitted under controlled conditions with all potential ignition sources prohibited in or near the area and with all equipment shut down.

12.4.6 Water-Cleaning Requirements. 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 and powder to a remote area is available.

12.4.7 Cleaning Frequency.

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

12.4.7.2 Regular, periodic cleaning of buildings and machinery, with all machinery idle and power off, shall be carried out as frequently as conditions warrant.

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

12.4.9 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.

12.4.10 Regular, periodic cleaning of fugitive metal dust from buildings and machinery shall be carried out as frequently as conditions warrant.

12.4.11 Fugitive metal dust shall be removed to a designated storage or disposal area.

12.4.12 Inspections.

12.4.12.1 Regular inspections shall be conducted to detect the accumulation of excessive fugitive metal dust on any portions of buildings or machinery not regularly cleaned in daily operations.

12.4.12.2 Records shall be kept of the inspections specified in 12.4.12.1.

12.4.13 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal dust or scrap.

12.4.14 Designated containers shall be used for the collection of fugitive metal dust.

12.4.15 Combustible or flammable liquid accidental spills shall be cleaned up immediately.

12.5* Electrical.

12.5.1* Grounding. All process equipment and all building steel shall be bonded and grounded.

12.5.2* In local areas of a plant where a hazardous quantity of 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*.

12.5.3 Electrical Equipment Maintenance.

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

12.5.3.2 Electrical equipment shall be inspected and cleaned at least once each year or more frequently if conditions warrant it.

12.5.4 Flashlights, electronic devices, and other portable electrical equipment shall be listed for use in hazardous locations.

12.5.5 All electrical equipment and wiring shall comply with *NFPA 70*, *National Electrical Code*.

12.5.6* In local areas of a plant where a hazardous quantity of 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*.

12.6 Personal Protective Equipment.

12.6.1 Outer clothing shall be clean, flame retardant, and nonstatic generating where combustible metal dust is present.

12.6.1.1 Outer clothing shall be designed to be removable.

12.6.1.2 Wool, silk, or synthetic fabrics that can accumulate high static electric charges shall not be used.

12.6.2 Work clothing shall be designed to minimize the accumulations of combustible metal dust (e.g., trousers shall not have cuffs).

12.6.3* Safety shoes shall be static dissipating, where necessary, shall have no exposed metal, and shall be appropriate for the type of operation taking place.

12.6.4* Clothing Fires.

12.6.4.1 Emergency procedures for handling clothing fires shall be established.

12.6.4.2 If deluge showers are installed, they shall be located such that water from the shower cannot enter dry metal powder–processing and –handling areas.

12.6.5* Emergency Procedures.

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

12.6.5.2 All employees shall be trained in the emergency procedures.

Chapter 13 Fire Prevention, Fire Protection, and Emergency Response

13.1 Applicability. 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.

13.2 Fire Prevention.

13.2.1 Inspection and Maintenance.

13.2.1.1 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.

13.2.1.2 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

13.2.1.3 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.

(A) The inspection shall be conducted at least quarterly.

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

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

13.2.2 Housekeeping.

13.2.2.1 Fugitive combustible metal dust shall not be allowed to accumulate.

13.2.2.2 Systematic cleaning of the specific section of the building containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as conditions warrant.

(A) The cleaning shall include machinery.

(B) 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.

(C) Chips or powder sweepings shall be removed to a designated storage or disposal area.

13.2.2.3 Bulk accumulations of fine combustible metals shall be removed by natural-fiber push brooms and spark-resistant scoops or shovels before vacuum cleaning equipment is used.

13.2.2.3.1 Cleanup of the bulk of spilled powder shall be accomplished using conductive, spark-resistant scoops and brooms or brushes that have natural-fiber bristles.

13.2.2.3.2 Vacuum cleaning, using vacuum cleaning systems designed and approved for handling combustible-metal dusts, shall be permitted only for small amounts of residual material remaining after preliminary cleanup.

13.2.2.3.3* Because of the inherent hazards associated with the use of vacuum cleaning systems and portable vacuum systems for finely divided combustible-metal dusts, special engineering analysis shall be given to the design, installation, maintenance, and use of such systems.

13.2.2.3.4 Blowing down of any surfaces by compressed air shall be prohibited except in areas that are otherwise impossible to clean and, where permitted, shall be performed under carefully controlled conditions with all potential ignition sources prohibited in or near the area and with all equipment shut down.

13.2.2.3.5 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.

13.2.2.3.6 Oil spills shall be cleaned up immediately.

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

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

13.2.2.3.9 Periodic inspections shall be conducted as frequently as conditions warrant to detect the excessive accumulation of combustible metals, chips, or powder on any portions of buildings or machinery not regularly cleaned during daily operations.

13.2.2.3.10 Records of the inspections specified in 13.2.2.3.9 shall be kept.

13.2.2.3.11 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.

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

13.2.3 Control of Ignition Sources.

13.2.3.1* Hot Work.

13.2.3.1.1 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 13.2.3.1.

13.2.3.1.2 Hot-work permits shall be required in any areas that contain combustible metals or combustible metal powders, fines, dust, or sponge.

13.2.3.1.3 Open flames, cutting or welding operations, 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.

13.2.3.1.4 All hot-work areas that require a permit shall be thoroughly cleaned of combustible metals or exposed combustible metal powders, fines, dust, or sponge before hot work is performed.

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

13.2.3.2 Smoking.

13.2.3.2.1* Smoking shall not be permitted in areas where combustible metal, sponge, chips, or powder is present.

13.2.3.2.2 Smoking shall be permitted only in designated areas.

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

13.2.3.2.4 Matches and lighters shall be prohibited in no-smoking areas.

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

13.2.3.3 Spark-Resistant Tools.

13.2.3.3.1 Where tools and utensils are used in areas handling combustible metals, powders, fines, or dusts, consideration shall be given to the risks associated with generating impact sparks and static electricity.

13.2.3.3.2* Tools used in the handling of combustible metal powder, dusts, or fines shall be electrically conductive and shall be made of spark-resistant materials.

13.2.3.3.3 Spark-resistant tools shall be used when repairs or adjustments are made on or around any machinery or apparatus where combustible metal dusts, fines, or powders are present and cannot be removed.

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

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

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

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

13.2.4.4 The wire between two bonding clips shall be verified as conductive.

13.2.4.5 Grounded and bonded bearings shall be used.

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

13.2.6 Bearings.

13.2.6.1 Ball or roller bearings shall be sealed against dust.

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

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

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

13.2.7 Control of Combustible Materials.

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

13.2.7.1.1 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).

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

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

13.2.7.2 Ordinary Combustible Storage.

13.2.7.2.1 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.

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

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

13.2.7.3.1 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.

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

13.2.8* Molten Metal.

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

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

13.3 Fire Protection.

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

13.3.1.1* Automatic sprinkler protection shall not be permitted in areas where combustible metals are produced or handled.

13.3.1.2* 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 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 metal powder.

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

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

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

13.3.1.6* 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

13.3.2 Sprinkler Protection for Alkali Metals.

13.3.2.1* 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.

13.3.2.2 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.

13.3.2.3 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.

13.3.2.4 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.

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

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

13.3.3* Extinguishing Agents and Application Techniques.

13.3.3.1* Only listed, Class D extinguishing agents and those agents shown to be effective for controlling combustible-metal fires shall be provided.

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

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

13.3.3.4 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*.

13.3.3.5 The following agents shall not be used as extinguishing agents on a combustible-metal fires because of adverse reactions or ineffectiveness:

(1) Water
(2) Foams
(3) Halon
(4) Carbon dioxide
(5)*Nitrogen (except on iron, steel, and alkali metals, excluding lithium)
(6) Halon replacement agents

13.3.3.6 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.

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

13.3.3.8 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."

13.3.3.9* Incipient fires in solvent-wetted powders shall be handled according to 13.3.3.9.1 or 13.3.3.9.2.

13.3.3.9.1 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.

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

13.3.3.9.2.1* 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 other listed Class D extinguishing agent, and the entire mass shall be allowed to cool until it reaches ambient temperature.

13.3.3.9.2.2* 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.

13.3.3.9.2.3 The material shall be handled in covered containers.

13.3.3.10 Applications of extinguishing agents shall be handled according to 13.3.3.10.1 through 13.3.3.10.4.

13.3.3.10.1* 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 Class D extinguishing powder in accordance with the manufacturer's instructions.

13.3.3.10.2 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.

13.3.3.10.3* 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.

13.3.3.10.4 Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing combustible-metal fires shall be permitted.

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

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

13.3.4* Personal Protective Equipment for Fire Fighting. Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding fire-fighting personnel assigned to a combustible-metal fire.

13.3.5 Fire-Fighting Activities.

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

13.3.5.2 In case of fire in the chips, turnings, or powder compact, the pan or tray shall not be disturbed or moved, except by an individual knowledgeable in the fire aspects of combustible metals, until the fire has been extinguished and the material has cooled to ambient temperature.

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

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

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

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

13.3.5.7 When drums or tote bins of burning materials can be moved safely, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

13.3.5.8 Processing Equipment.

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

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

13.3.5.9 Alkali Metals Fire-Fighting Procedures.

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

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

13.3.6 Fire-Fighting Organization.

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

(A) Personnel other than trained personnel shall be evacuated from the area.

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

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

13.3.6.2.1 Training shall include all possible contingencies.

13.3.6.2.2* 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.

13.4* Emergency Response.

13.4.1 The following shall be considered in the proper handling of fires:

(1)*A good size-up and identification of involved materials shall be made.
(2) Material safety data sheets shall be obtained for the involved products, and if available, those familiar with the product and hazards shall be contacted.
(3) It shall be determined if a fire can be safely isolated and allowed to burn out.
(4) Uninvolved product and exposures can be protected by hose streams if adequate precautions are taken. It is extremely important that care is taken to prevent any runoff from hose streams from coming into contact with burning material.
(5) If fire is burning in a closed container, such as a dust collection system, argon or helium (or nitrogen for alkali metals) can be effective in controlling the fire by placing an inert blanket over the fire where an adequate delivery system is available and personnel safety is considered. Evaluation of explosion potential shall also be considered.
(6) Extreme caution shall be taken for fires involving combustible-metal powders, dusts, and fines. Explosions are possible with these products, especially if the product becomes airborne with an available ignition source.
(7) Small and incipient fires shall be permitted to be contained utilizing Class D extinguishing agents, dry sand, or dry salt.
(8)*Extreme caution shall be taken with fires involving large quantities of product within structures.
(9) Most fires involving combustible metals cannot be extinguished in a manner other than by providing an inert atmosphere of argon or helium (and also nitrogen for alkali metals) if the product is dry. In most cases, the fire is controlled by application of argon or helium (or nitrogen for alkali metals) or by the development of an oxide crust. The temperature of the material involved can remain extremely hot, and the fire can flare up again if the product is disturbed prior to complete oxidation of the product or self-extinguishment.
(10) Water in contact with molten combustible metals will result in violent steam and hydrogen explosions and reactions.
(11) Large fires may be impossible to extinguish. The best approach is to isolate the material as much as possible, if it can be done safely. Exposures shall be permitted to be protected with water streams if adequate drainage is present to prevent the contact of water with burning material. The fire shall be permitted to be allowed to burn itself out naturally to minimize hazards to personnel and losses to exposures.

13.5 Emergency Preparedness.

13.5.1 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.

13.5.2* 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.

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

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

13.5.2.3 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

13.5.2.4 The following aspects of handling combustible metal fires shall be considered in emergency preparedness planning:

(1) Water, when applied to burning combustible metals, results in an increase in burning intensity and possible explosion, particularly if alkali metals are present.
(2) Application of carbon dioxide on combustible-metal fire has results similar to the application of water; the carbon dioxide adds to the intensity of the burning. Most combustible metals ignite and burn in 100 percent carbon dioxide atmospheres.
(3) Dry chemical extinguishers react with alkali metals and intensify the fire. 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.

(4) Halogenated extinguishing agents used on alkali metals can result in an explosion and will have a detrimental effect on other combustible metal fires, with the decomposition producing hazardous by-products.
(5) A primary metal fire displays intense orange-to-white flame and can be associated with a heavy or large production of white/gray smoke.
(6) When water is applied to nonalkali combustible metal, it actually disassociates to the basic compounds, oxygen and hydrogen. Similar results occur with carbon dioxide.
(7) When water is applied to alkali metals, hydroxides and hydrogen are generated immediately.
(8) Fires involving combustible metals that contain moisture exhibit more intense burning characteristics than dry product.
(9) Extreme heat production 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.
(10) Dusts, fines, and powders of combustible metals present an explosion hazard, especially in confined spaces.
(11) 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.
(12) Zirconium and titanium powder can exhibit pyrophoric characteristics.
(13) 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.
(14) 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.
(15) The sponge product of most combustible metals burns at a slower rate but still produces tremendous heat.
(16) 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. Burning metal destroys asphalt and extracts moisture from rock.
(17) Fires involving non-alkali combustible metals cannot be extinguished. Unless they are placed in an inert atmosphere of argon or helium, they can only be controlled. When possible, fires involving large quantities should be allowed to cool for at least 24 hours prior to being disturbed, to prevent reignition. Fires will oxidize metal.
(18) Alkali metal fires can be extinguished with the suitable extinguishing agents correctly applied.
(19) Combustible metal fines and powders that are stored and contain moisture can produce hydrogen gas.
(20) Combustible metal fines and dusts that are not oxidized and that come into contact with iron oxides can result in thermite reactions.

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

13.5.4* All employees in areas handling combustible metals shall be trained 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 shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire-extinguishing equipment.
(3) All employees shall be taught the permissible methods for fighting incipient fires and for isolating fires.
(4) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire shall be explained.
(5) Employees shall be trained in the means of safe and proper evacuation of work areas.
(6) Equipment operation, start-up and shutdown, and response to upset conditions shall be explained.
(7) Necessity for functioning of related fire and explosion protection systems shall be explained.
(8) Emergency response plans shall be explained.

13.5.4.1 Training shall be documented.

13.5.5 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.

13.5.6 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.

13.5.7* Clothing Fires.

13.5.7.1 Emergency procedures for handling clothing fires shall be established.

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

Chapter 14 Combustible Metal Recycling Facilities

14.1 General. The requirements of this chapter shall apply to new and existing facilities where combustible metals are recycled.

14.1.1 This chapter shall apply to companies recycling combustible metals from outside sources.

14.1.2* The requirements of Chapter 13 shall apply to recycling facilities.

14.1.3* When the combustibility of a metal is unknown, the metal shall be tested as specified in Chapter 4 to determine whether it is a combustible metal.

14.2 Receiving Criteria. Incoming material shall be inspected for acceptance criteria.

14.2.1 Acceptance criteria for combustible metals being recycled shall be established by the recycler.

14.2.2 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) MSDS
(7) Certificate of insurance
(8) Authorized signature of acceptance of material

14.2.3 The acceptance criteria shall be documented and available for review by the AHJ.

14.2.4* Material that cannot be stored, handled, or processed by the receiving facility shall be rejected.

14.2.5 Rejected material shall be returned to the supplier within 5 working days or disposed of in accordance with local, state, and federal regulations.

14.2.6* Rejected material shall be labeled and segregated in an area identified for storage of rejected material.

14.3 Storage of Combustible Metals for Recycling.

14.3.1 Containers and areas where combustible metals are stored shall be labeled or identified as to the type of metal stored, form, and date of receipt.

14.3.2 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

14.3.3 The tracking records shall be available for inspection by the authority having jurisdiction.

14.3.4 Area and container labels or identification shall reference the appropriate material safety data sheets (MSDSs) on file.

14.3.5 Buildings used for the indoor storage of combustible metal shall be of noncombustible construction and shall meet the requirements of Section 12.1.

14.3.6 Combustible metals shall be separated from other combustible materials.

(1) 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.
(2) Outside storage of dry combustible metals shall be permitted if such storage is separated from buildings or personnel and precautions are exercised to prevent the combustible metals from becoming wet.

14.3.7 Wet Combustible Metals.

14.3.7.1 Wet combustible metals shall be stored at an outside location identified for that use.

14.3.7.2* Wet combustible metals shall be kept under water in a covered and vented container.

14.3.7.2.1 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).

14.3.7.2.2 Containers of wet combustible metals shall not be stacked.

14.3.8 Container Limits.

14.3.8.1 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).

14.3.8.2 The maximum weight of any material container and/or pallet shall be capable of being moved by the available equipment.

14.3.9 Stacked storage shall be arranged to ensure stability.

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

14.3.11 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).

14.3.12 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.

14.3.13 Solid combustible metals, such as clippings and castings, shall be stored in noncombustible bins or containers.

14.3.14 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid combustible metal.

14.3.15 The use of automatic sprinklers in buildings or areas where combustible metals are stored shall be prohibited.

14.3.16 Periodic inspections of the facility shall be in accordance with 13.2.1.

14.4 Processing.

14.4.1 The recyclers shall determine the combustibility/explosivity characteristics of any intermediate or final material generated as a result of on-site processing.

14.4.1.1* Documentation of the determination in 14.4.1 shall be maintained and available for review by the authority having jurisdiction.

14.4.2 For all processing of combustible metals for which there are specific chapters, the requirements of those chapters shall apply.

14.4.3 For all other combustible metal and alloy processing, the requirements of Chapter 12 shall apply.

14.4.4 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.*

14.4.5 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.*

14.5 Emergency Preparedness.

14.5.1 Procedures.

14.5.1.1 Emergency procedures shall be established to address fire and explosion events.

14.5.1.2 The emergency procedures shall be documented.

14.5.2* Training.

14.5.2.1 All employees shall be trained in the emergency procedures and the hazards of combustible metals.

14.5.2.2 Training shall be documented and available for inspection by the authority having jurisdiction.

14.6 Ignition Sources. Control of ignition sources shall be in accordance with the requirements of 13.2.3.

14.7 Waste Disposal. A disposal plan for all combustible metals included in process residues shall be documented and made available to the authority having jurisdiction.

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.1.1.3 Products or materials that have the characteristics of a combustible metal should have a material safety data sheet (MSDS) 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.1.1.5 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.1.1.9 A combustible metal is a metal that meets the criteria for combustibility as defined in Chapter 4. The quantities listed in Table 1.1.9 are for the entire occupancy, not for individual fire control areas.

A.1.4.2 The requirements identified in Chapter 13 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 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 Combustible Metal Dust. Any time a combustible dust is processed or handled, a potential for explosion or fire exists. The degree of hazard varies, depending on the type of combustible dust, conditions, amount of material present, and processing methods used.

A dust explosion requires the following four conditions:

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

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

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

The following information can be determined by optional testing:

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

Table A.1.1.3 Characteristics of Certain Metals

Metal	Form	Melting Point (°C)	Boiling Point (°C)	Solid Metal Ignition (°C)	Ignition Layer (°C)	Temp. Cloud (°C)	MIE (mJ)	MEC (g/m^3)	K_{St} (bar · m/s)	LOC (%)	WR	PA
Aluminum	Solid	660	2452	555								
Aluminum dust	Dust				650	750	50	85	290	5	Yes	
Barium	Solid	725	1140	175								
Bronze powder	Dust								31			
Calcium	Solid	824	1440	704								
Calcium/silicon alumina	Dust								200			
Ferrochrome	Dust								86			
Ferromanganese	Dust								84			
Hafnium	Solid or dust	2223	5399									
Iron	Solid or dust	1535	3000	930					50			
Lithium	Solid	186	1336	180								
Magnesium	Solid	650	1110	623								
Magnesium dust	Dust											
Manganese	Dust											
Molybdenum	Dust											
Niobium	Dust											
Plutonium	Solid	640	3315	600								
Potassium	Solid	62	760	69								
Silicon	Dust								126			
Sodium	Solid	98	880	115								
Strontium	Solid	774	1150	720								
Tantalum	Solid											
Tantalum powder	Dust											
Thorium	Solid	1845	4500	500								
Titanium	Solid	1727	3260	1593								
Titanium dust	Dust											
Uranium	Solid	1132	3815	3815								
Zinc	Solid	419	907	900								
Zinc dust	Dust											
Zirconium	Solid	1830	3577	1400								
Zirconium powder	Dust											

Note: The data in this table are intended to be representative. Actual test data should be used to characterize specific metals.

Key:

K_{St} = deflagration index

LOC = limiting oxygen concentration in nitrogen

MEC = minimum explosible concentration

MIE = minimum ignition energy

PA = storage under protective atmosphere; data not yet available

WR = water-reactive metal

Conversion factors:

$°F = 1.8\ (°C) + 32$

$1\ mJ = 0.95 \times 10^{-6}\ Btu$

$1\ g/m^3 = 6.24 \times 10^{-5}\ lb/ft^3$

$1\ bar \cdot m/s = 328\ (kPa \cdot ft)/s$

Samples to be submitted for testing should not be allowed to oxidize to a degree significantly greater than the degree of oxidation that would take place at the actual hazard. This usually involves taking samples as soon as possible after the aluminum dust is produced and then storing and shipping the samples in an airtight container purged with an inert gas.

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.3.3.14 Fire-Resistive. The requirements are described in NFPA 220, *Standard on Types of Building Construction.*

A.3.3.18 Heavy Casting. Castings less than 11.3 kg (25 lb) are considered light castings.

A.3.3.20 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.3.3.22.2 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 MSDS 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.3.3.22.3 Spark-Resistant Material. See AMCA Standard 99-1401-86, "Classifications for Spark Resistant Construction," for additional information.

A.3.3.24 Mesh Size. Table A.3.3.24 provides mesh sizes.

Table A.3.3.24 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.3.3.25.2 Combustible Metal. See A.1.1.3 for further information on determining the characteristics of metals.

A.3.3.26 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.3.3.27 Noncombustible. Materials reported as noncombustible, where tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, are considered noncombustible materials.

A.3.3.29.1 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.3.3.29.3 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.3.3.29.4 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.3.3.30 Powder Production Plant. Facilities or buildings in which powder or combustible dust is produced incidentally to operations are not considered powder production plants.

A.3.3.34 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.3.3.39 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.

A.4.2.1 This preliminary screening test used to demonstrate fire risk is the basis for the regulations governing the transport of dangerous goods for 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 1,000°C (1832°F) from a gas burner] [minimum diameter of 5 mm (0.20 in.)] is applied to one end of the powder train until the powder ignites or for a maximum of 5 minutes. It should be noted whether combustion propagates along 200 mm (7.87 in.) of the train within a 20-minute test period.
(3) If the substance does not ignite and propagate combustion either by burning with flame or smoldering along 200 mm (7.87 in.) of the powder train within the 20-minute test period, the material should not be considered a combustible metal, metal powder, or dust.
(4) If the substance propagates burning of the 200 mm (7.87 in.) length of the powder train in less than 20 minutes, the full burning rate test should be conducted.

Because the specific form of the combustible metal, metal powder, or dust and the properties of the form determine the flammability and degree of combustibility of the material, it is critical that the substance be tested precisely in the condition in which it is processed or handled. Changes in particle size distribution, moisture content, degree of fines, and chemical composition can radically change the results. No generic substitute is allowable for accurate determination of fire risk.

A.4.2.4 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 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, it is mandatory that 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.

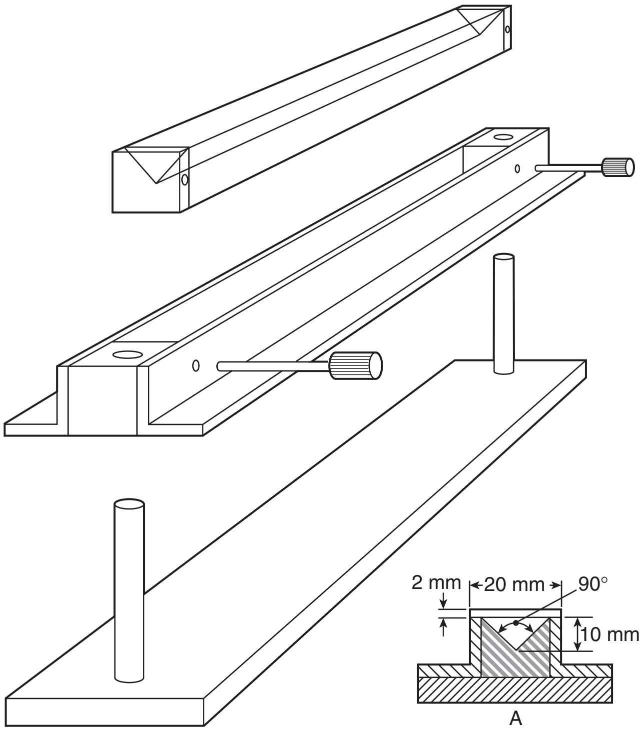
A.4.2.5 If propagation of the powder train occurs along a length of 200 mm (7.87 in.) in 20 minutes or less, the burning rate test is required. The burning rate test requires specific preparation of the powder sample. The sample is prepared in a specific fixture as shown in Figure A.4.2.5.

Preparation of the sample for the burning rate test should be done according to the following description.

The powdered or granular substance, in its commercial form, must be loosely filled into a mold. The mold, which must be 250 mm (9.84 in.) long with a triangular cross section of inner height 10 mm (0.39 in.) and width 20 mm (0.79 in.), is used to form the train for the burning rate test. On both sides of the mold, in the longitudinal direction, two metal sheets are mounted as lateral limitations that extend 2 mm beyond the upper edge of the triangular cross section. An impervious, noncombustible, low-heat-conducting plate is used to support the sample train. The mold is then dropped three times from a height of 20 mm (0.79 in.) onto a solid surface. The lateral limitations are then removed, and the impervious noncombustible low-heat-conducting plate is placed on top of the mold, the apparatus inverted, and the mold removed. Pasty substances must be spread on a noncombustible surface in the form of a rope 250 mm (9.84 in.) in length with a cross section of about 100 mm^2 (0.16 $in.^2$). In the case of a moisture-sensitive substance, the test must be carried out as quickly as possible after its removal from the container.

Test conditions are as follows:

(1) The pile is arranged across the draft in a fume cupboard. The airspeed is sufficient to prevent fumes from escaping into the laboratory and is not varied during the test. A draft screen can be erected around the apparatus.
(2) Any suitable ignition source such as a small flame or hot wire of minimum temperature 1000°C (1832°F) is used to ignite the pile at one end. When the pile has burned a distance of 80 mm (3.15 in.), the rate of burning is measured over the 100 mm (3.94 in.). The test is performed six times using a clean cool plate each time, unless a positive result is observed earlier.



Note: For U.S. standard measurements, 1 mm = 0.039 in.

FIGURE A.4.2.5 Fixture for Preparation of Sample for Burning Rate Test.

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.4.3.1 Table A.4.3.1 gives ignition and explosion data on various sizes of powders.

A.4.3.2 This is a "go" or "no go" test to determine whether the sample material is capable of explosion. Several variations on the test exist. Generally, all the tests use a modified Hartmann tube (a vertically mounted acrylic/glass tube 63 mm in diameter with a typical volume of 1 L). The Hartmann tube is outfitted with a compressed-air dust dispersion system and a set of electrodes at the bottom. Normally, a constant arc of 10 J is applied across the electrodes.

A.4.3.3 Explosive properties are dramatically affected by changes in physical properties, chemical composition, particle size distribution, amount of fines, and mean particle size. 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.

A.4.3.4 Varying amounts of the test powder should be suspended in the tube, using compressed air, to determine whether an explosion occurs. Varying the amount of the dust provides testing of the sample at various dust concentrations. A minimum of six concentrations should be selected. A minimum of three test repetitions at each concentration should be performed. If any test shows combustion within the dispersed cloud, the result is considered positive, and the material is in a combustible form. The tests can be stopped at the first positive test.

MIE Test. The testing for the MIE of a combustible particulate is carried out in accordance with the following recognized international standards: ASTM E 2019, *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.

Explosion Severity Test. The explosion severity test is conducted to determine the explosion severity of a dust cloud under specified conditions. This test serves to identify the maximum explosive 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 BS 6713-1/ISO 6184-1, *Explosion Protection Systems. Part I: Method for Determination of Explosion Indices of Combustible Dusts in Air.*

The test regimen employs a 20 L 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 ignitors. The test is done 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 tests are repeated in triplicate, and the values obtained at the optimum dust concentration are then averaged to obtain P_{max} and dP/dt_{max}.

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 to a volume of 1 m^3. Materials are classified according to the *St* class system in Table A.4.3.4. The higher a powder *St* class number, the more energetic the explosion and the greater the speed of the explosion.

LOC Test. The purpose of the test to determine the LOC is to find the oxygen concentration below which dispersed dust of the sample is not possible.

The test is conducted in accordance with BS 6713-1/ISO 6184-1, *Explosion Protection Systems. Part I: Method for Determination of Explosion Indices of Combustible Dusts in Air.*

The LOC test is conducted using the 20 L spherical explosion chamber described for the explosion severity test.

The protocol for the LOC test requires that the optimum powder concentration for explosion be determined. Once this value is known, the testing for LOC can commence. This value is required because the ratio of oxygen to fuel must be held

Table A.4.3.1 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/s)	K_{St} (bar·m/s)	Sample Concentration That Corresponds to P_{max} and dP/dt_{max}	MIE (mJ)	LOC (%)	Most Easily Ignitable 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^3 = 0.000062 lb/ft^3; 1 bar/s = 14.5 psi/s; 1 bar·m/s = 0.226 psi·ft/s.

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 E 1515, *Standard Test Method for Minimum Explosible Concentration of Combustible Dusts*; MIE: ASTM E 2019, *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 E 1226, *Standard Test Method for Pressure and Rate of Pressure Rise for Combustible Dusts*; LOC: ASTM E 2079, *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.

Table A.4.3.4 Explosive Energy Classification

***St* Class**	**K_{St} (bar·m·s^{-1})**
St 1	>0–200
St 2	201–300
St 3	>300

constant. 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 ten years. Currently, some laboratories define an ignition as a measured value of pressure during the test that is equal to or greater than 0.2 bar. Some test laboratories use a value of 0.4 bar.

MEC Test. The test to determine the MEC of a combustible dust is performed using BS 6713-1/ISO 6184-1, *Explosion Protection Systems. Part I: Method for Determination of Explosion Indices of Combustible Dusts in Air.*

The test is performed using the 20 L 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 0.4 bar.

The LOC test is critical for determining the dust loading of dust collection systems as well as determining when fugitive dust accumulation has reached a point where explosion danger is manifest.

A.5.1 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 MSDS 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.5.1.1 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.5.1.2 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.5.1.3 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.5.1.3.1 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.5.1.3.3 The longer the material is stored, the greater the risk of hazardous reactions.

A.5.2 Consideration should be given to automatic fire detection systems in alkali metal production plants to ensure life safety.

A.5.2.1.4 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.5.2.1.6 Because of the potential presence of mineral oil on the floor, nonslip surfaces should be provided.

A.5.2.1.7 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.5.2.2.1 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.5.2.3 A ridged or peaked roof that allows for natural ventilation of hydrogen is recommended.

A.5.3.1.4 See A.5.4.1.3.

A.5.3.1.6 See NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work.*

A.5.3.1.7 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.5.3.2.1 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 MSDS 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.5.3.2.2.2 Organic materials in the presence of oxides of potassium or NaK can create an explosive shock-sensitive mixture.

A.5.3.2.3 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.5.3.2.4 If left open for more than 15 minutes, the container should be purged with a gas that is inert to alkali metals.

A.5.3.3.1 Organic materials in the presence of oxides of potassium or NaK can create an explosive shock-sensitive mixture.

A.5.4.1.1 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.5.4.1.3 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.5.5 Because of the unique nature of alkali metal fires, a comprehensive fire protection plan is necessary where alkali metal is processed, handled, used, or stored. 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.5.6.1 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.5.6.2 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.5.6.2.5 Fire risk is significantly reduced when the outer clothing layer is kept dry.

A.6.1.2.10 For information on deflagration venting, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.6.1.3.2 See Section 5.11 and Chapter 28 of NFPA *101*, *Life Safety Code*.

A.6.1.4.1 For information on deflagration venting, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.6.1.5.1 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.1.6.2 See 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.

A.6.1.8.1.3 Temperature-sensing elements connected to alarms or machine stop switches should be employed for locations where overheating of bearings or other elements could be anticipated.

A.6.1.8.2.3 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.6.1.8.2.4.1 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.6.1.9.8.2 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A.6.1.9.8.3 Any moisture entering the system can react with the aluminum powder, 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.6.1.9.8.5 Typical margins of safety used for pneumatic dust handling are 25 percent to 50 percent of the MEC. Published data indicate an MEC of 45 g/m^3 (0.045 oz/ft^3) for atomized aluminum powder. MEC data for aluminum with varying particle size distributions can be found in U.S. Bureau of Mines, RI 6516, "Explosibility of Metal Powders." Although the aluminum 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. Also, the powder in the conveying line from the atomizer to the collector will, of necessity, approach the MEC.

A.6.1.9.8.6 For information on spacing and sizing of ductwork deflagration vents, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting.*

A.6.1.9.9.1 Aluminum and aluminum 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 aluminum 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.

A.6.1.9.9.2 Oxygen limits of 3 percent to 5 percent have been maintained in aluminum powder systems using a controlled flue gas. Other limits are applicable where other inert gases are used. See U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders."

A completely inert gas can be used if the powder so produced will not be exposed to air. Aluminum powder produced without oxygen is more highly reactive than aluminum powder produced by conventional means.

A.6.1.9.10.1 Information on spark-resistant fans and blowers can be found in AMCA Standard No. 99-0401-86, "Classifications for Spark Resistant Construction."

A.6.1.9.10.4 Ultimately, all fans or blowers in dust collection systems accumulate sufficient powder to become a potential explosion hazard.

A.6.1.9.10.5 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.6.1.10.1 A high-efficiency cyclone-type collector presents less 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- or bag-type 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 aluminum 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 be such to 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.6.1.10.1.2 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.6.1.10.1.5 For information on precautions for static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A.6.1.10.1.7 Explosion venting is especially important for combustible aluminum 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 aluminum dust explosion.

A.6.1.10.3 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.6.1.11.4 Materials incompatible with aluminum powder include, but are not limited to, oxidizers, organic peroxides, inorganic acids, and materials identified in the material safety data sheet (MSDS).

A.6.2.3 Certain nondusting grades of aluminum flake powder are being produced. These powders tend to reduce the hazard of inadvertently caused dust clouds. They are as combustible as regular grades of flake powder and, once levitated into a cloud, exhibit the same explosibility characteristics. For those reasons, the same precautions must be observed as for normal grades of powder.

A.6.2.4.1 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.6.2.4.1.1 See A.6.2.4.1

A.6.2.4.1.2 See A.6.2.4.1.

A.6.2.4.1.5 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 lower flammable limit (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.6.2.4.2.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.2.4.2.4 See 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.

A.6.2.5 See Figure A.6.2.5(a) and Figure A.6.2.5(b) for examples of dust collection at bag dump stations.

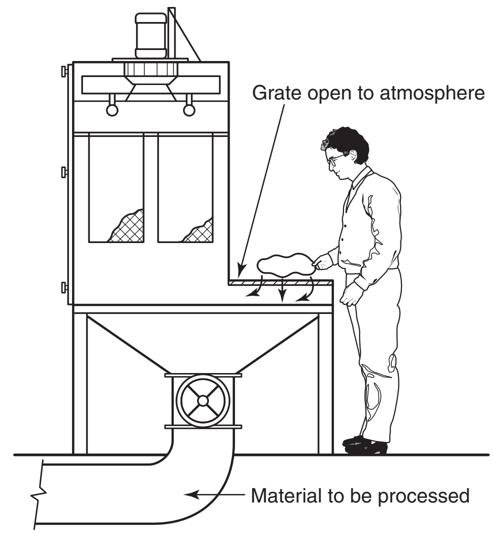


FIGURE A.6.2.5(a) Example of Unacceptable Manual Bag Dump Station in Which Operator Is Exposed to Potential Fire or Explosion.

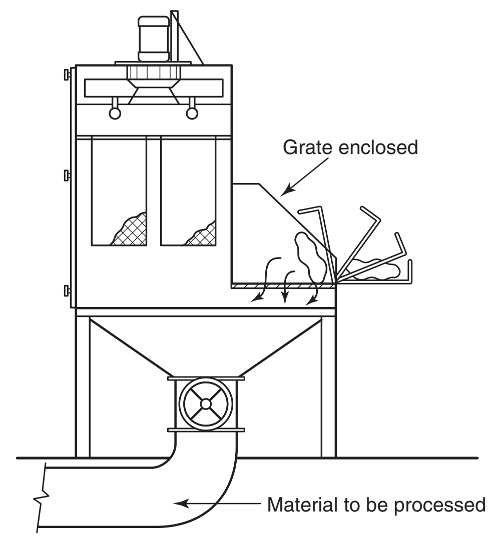


FIGURE A.6.2.5(b) Example of Acceptable Station in Which Bag Dump Operation Is Automatic.

A.6.3.1 There are two recognized methods of collecting aluminum dust in industrial operations. Wet dust collectors are located indoors near the point of dust generation; dry-type collectors are located outdoors as close as possible to the point of dust generation.

A.6.3.2.1 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.6.3.2.3 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.6.3.2.5 Figure A.6.3.2.5 is an example of a media-type dust collector. The figure shows major system components.

A.6.3.2.5.1 See Figure A.6.3.2.5.1.

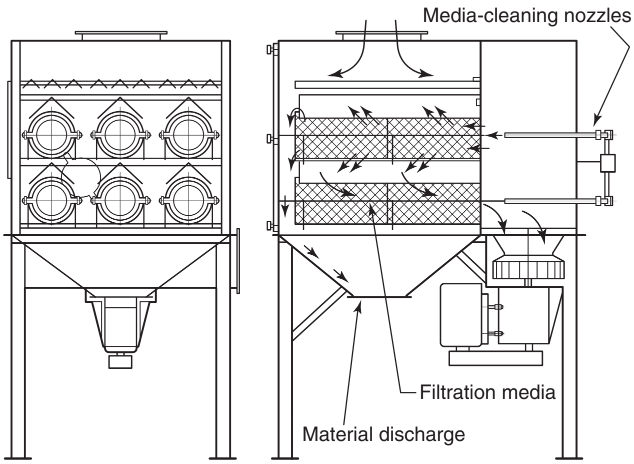


FIGURE A.6.3.2.5 Example of a Fixed Media-Type Dust Collector.

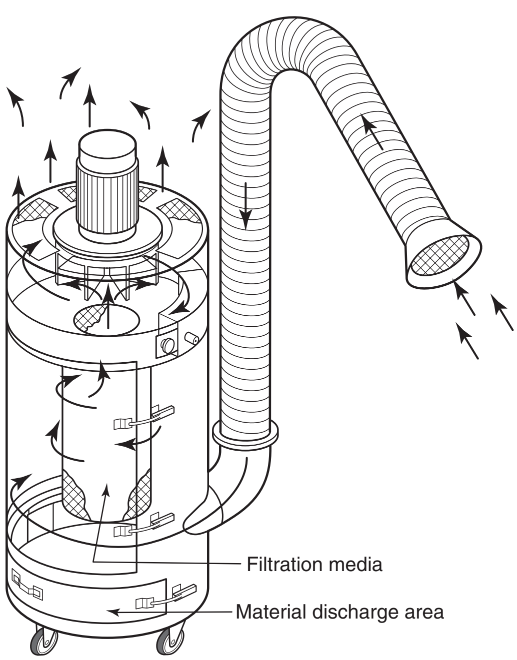


FIGURE A.6.3.2.5.1 Example of a Portable Media-Type Dust Collector.

A.6.3.2.5.2 A high-efficiency cyclone-type collector presents less 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-type, bag-type, 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 aluminum 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 be such as to 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.6.3.2.5.3 For the method to calculate the length of a fireball issuing from a vented collector, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.6.3.2.6 Under certain circumstances, such as impact with rusted iron or steel, aluminum cannot safely be considered to be nonsparking, because a minor thermite reaction can be initiated. For details, refer to Eisner, "Aluminum and the Gas Ignition Risk."

A.6.3.3.3 U.S. Bureau of Mines, RI 6516, "Explosibility of Metal Powders," reports the results of tests conducted on 89 different samples of aluminum 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 620 kPag (90 psig).

A.6.3.3.4 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.6.3.3.6 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.3.4.1 The reaction of water and aluminum produces hydrogen. Hydrogen is extremely flammable and very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.6.3.4.2 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.6.3.4.4 Figure A.6.3.4.4(a), Figure A.6.3.4.4(b), and Figure A.6.3.4.4(c) show examples of liquid precipitation collectors.

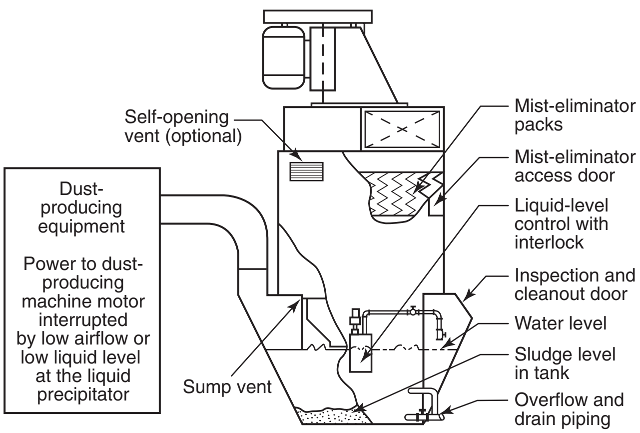


FIGURE A.6.3.4.4(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

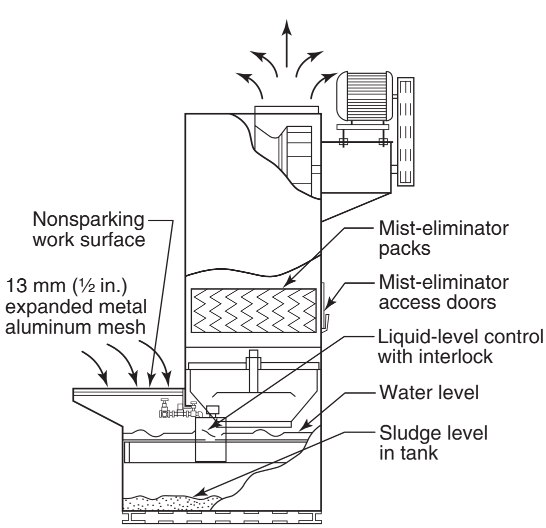


FIGURE A.6.3.4.4(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

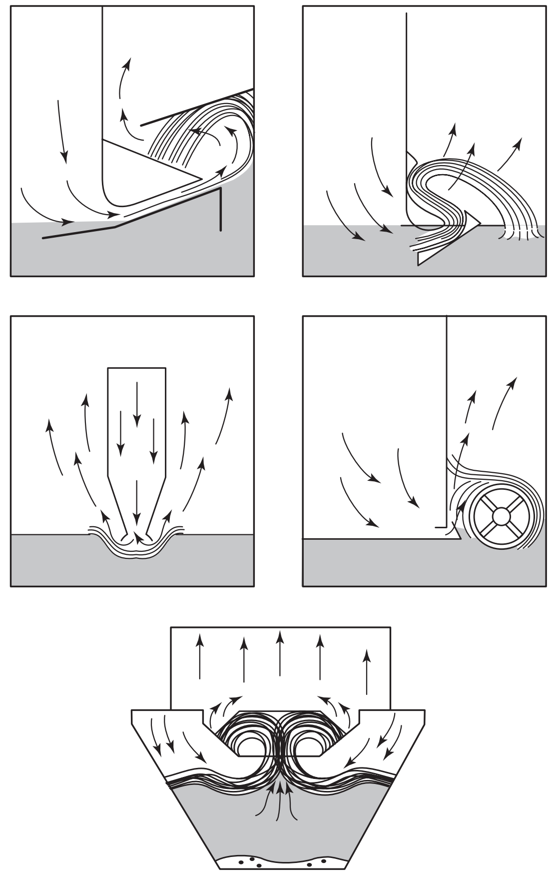


FIGURE A.6.3.4.4(c) Five Methods of Precipitating Dust in Precipitators.

A.6.3.4.5 It should be remembered that wetted dust that is not submerged under a cover of water is highly flammable and very dangerous.

A.6.3.4.6.1 The reaction of aluminum with water produces hydrogen, which is highly flammable.

A.6.3.4.8.2 Containers preferably should not hold more than 23 kg (50 lb) each.

A.6.3.4.8.4 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. 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 aluminum powder plants.

A.6.3.5.2 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.6.3.5.6 Explosion venting is especially important for combustible aluminum dust, due to the high maximum explosion pressures reached and the extremely high rate of pressure rise. For information on 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 aluminum dust explosion.

A.6.3.7.1 If a sufficient coolant flow is not used, improperly designed or dull tools can produce high temperatures at the tool-workpiece interface, potentially causing ignition of the turnings.

A.6.3.7.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.3.8.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.4.2.1 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.6.4.3 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. The dust collector should be located outside the building, preferably more than 15 m (50 ft) away. If the collector is located closer than 15 m (50 ft), it should be surrounded by a strong steel shield, cylindrical in shape and open at the top, or closed with a light, unfastened cover. The shield is closed at the bottom and designed to withstand a blast pressure of 1380 kPa (200 psi). Such a protective barricade will direct an explosion upward and could protect both property and personnel. All suction lines should be provided with explosion vents and antiflashback valves.

A.6.4.3.2 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.4.3.4 Improper use of vacuum cleaners for aluminum powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.5.1 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 6.5.2 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.

A.6.5.2.1 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 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.6.5.2.4 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.6.5.2.6.3 Class B extinguishing agents usually will greatly accelerate combustible aluminum dust fires and can cause burning metal to explode.

A.6.5.3 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 semidry 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.6.5.3.2 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.6.5.3.3.1 Re-ignition can occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material should be immediately smothered.

A.6.5.3.3.3 Materials preferably should be handled in quantities of not more than 11 L (3 gal) each in 19 L (5 gal) containers.

A.6.5.3.4.6 For guidance on design criteria for fire flow containment, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.6.5.4.1.1 For the automatic sprinkler provisions for storage and use of flammable and combustible liquids, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.6.5.5.3 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 aluminum powder and paste fires. In the interest of their own safety, fire fighters should be directed by the plant's safety officer or fire-fighting officer.

A.6.5.6 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.6.5.7.3 Under certain circumstances, such as impact 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.6.6.2.3 Where static dissipative safety shoes are used, a testing program to confirm that the shoes are static dissipating should be in place.

A.6.6.2.4 Fire blankets have been found to be effective for extinguishing clothing fires. They should be distributed in areas where water is excluded from the plant area.

A.6.6.3.2 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.7.1.4.3 See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.7.1.5 See NFPA 77, *Recommended Practice on Static Electricity*.

A.7.1.6.2 See also 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.

A.7.2.1 Chips, turnings, powders, or swarf that is being preheated or charged to melting pots will autoignite at temperatures below that of the solid metal. Solids should be free of these smaller particles, which can ignite and, in turn, ignite the solids. There should be no depression directly beneath the magnesium storage area where water can accumulate or flow during a fire.

A.7.2.1.1.2 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.7.2.1.2 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.7.2.1.4 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.7.2.2 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.7.2.2.3 See NFPA 86, *Standard for Ovens and Furnaces*.

A.7.2.2.4(B) The secondary set of temperature controls should cut off fuel or power to the heat-treating furnace at a temperature that is only slightly above the desired operating temperature.

A.7.2.2.7 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.7.2.2.9 Heating magnesium in the presence of oxidizers can result in combustion. Special salt fluxes can be safely used for dip brazing of magnesium.

A.7.2.2.10 Magnesium and aluminum form a eutectic alloy with considerably lower melting temperatures and autoignition temperatures than either parent metal.

A.7.2.2.11 There is a potential for a thermite reaction between magnesium or a magnesium alloy and iron oxide at elevated temperatures.

A.7.3.1 Flashing of chips during machining should be minimized by any of the following methods:

(1) Keeping the surface speed below 1.5 m/s (300 ft/min) or above 11 m/s (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.7.3.1.2 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.7.3.2.4.1 Interaction between magnesium fines and aluminum alloy fines (if the aluminum contains more than ½ 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.6.3.4.4(a), Figure A.6.3.4.4(b), and Figure A.6.3.4.4(c).]*

A.7.3.2.4.2 See "Industrial Ventilation: A Manual of Recommended Practice," Figure 4-14, Range of Particle Size, Concentration, and Collector Performance. One pound is equivalent to 7000 grains. The maximum concentration of less than 100 mesh magnesium dust should never exceed 0.03 g/L (0.03 oz/ft^3) of air, which is the minimum explosible concentration (MEC).

MECs for magnesium dust 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.7.3.2.4.10 Interaction between magnesium fines and aluminum alloy fines (if the aluminum contains more than ½ 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.

A.7.3.2.5.6 See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, for guidance on explosion venting.

A.7.3.3.3 Standard commercial industrial vacuum cleaners should not be used, because they are not safe for use with magnesium.

A.7.3.4.1 See 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.

A.7.3.5 See NFPA 77, *Recommended Practice on Static Electricity*.

A.7.3.6.3 Attention is called to the hazardous conditions that can 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 magnesium powder plants.

A.7.3.6.4 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.7.4.1.4 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.7.4.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.7.4.2.3 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.7.5.1.1 Special attention is necessary to ensure that the magnesium powder is not exposed to moisture.

A.7.5.2.2 Completely inert gas cannot be used as an inerting medium, because the magnesium 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.7.5.2.5 Higher conveying velocities are more desirable and increase safety.

A.7.5.3.1 For information on explosion vents, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. Ductwork vent–spacing guidelines in NFPA 68 do not apply to K_{St} values greater than 300 bar·m/s (14,268 psi·ft/s).

A.7.5.3.2 See NFPA 69, *Standard on Explosion Prevention Systems*.

A.7.5.3.6 See NFPA 77, *Recommended Practice on Static Electricity*.

A.7.5.4.1 Information on spark-resistant fans and blowers can be found in AMCA Standard 99-0401-86, "Classifications for Spark Resistant Construction."

A.7.5.5.4 See NFPA 77, *Recommended Practice on Static Electricity*.

A.7.5.5.5 Explosion venting is especially important for combustible magnesium 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 magnesium dust explosion.

A.7.6.1.2 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. The dust collector should be located outside the building, preferably more than 15 m (50 ft) away. If the collector is located closer than 15 m (50 ft), it is usually surrounded by a strong steel shield, cylindrical in shape and open at the top, or closed with a light, unfastened cover. The shield is closed at the bottom and designed to withstand a blast with a gauge pressure of 1380 kPa (200 psi). Such a protective barricade will direct an explosion upward and can protect both property and personnel. All suction lines should be provided with explosion vents and antiflashback valves.

A.7.6.1.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.7.6.1.2.4 Improper use of vacuum cleaners for magnesium powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.7.7.1 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.7.7.1.3 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.7.7.1.3.4.2(2) See NFPA 221, *Standard for High Challenge Fire Walls, Fire Walls, and Fire Barrier Walls*, for wall construction details.

A.7.7.2.3 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.7.7.2.7 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.7.7.3.5 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.7.7.5.4 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.7.7.6.6 For design information, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. See 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.

A.7.7.6.7 The safest manner of storage is achieved using no stacking.

A.7.7.7.1 Because the magnesium portions of parts and components can exhibit the burning characteristics of magnesium when involved in a fire, storage plans and arrangements should be designed to mitigate the fire hazards associated with burning magnesium.

Assemblies in which magnesium is a minority component might or might not exhibit burning behavior similar to a fire involving pure magnesium, depending on the following:

(1) Whether or not the magnesium is exposed on the outside of the assembly
(2) How fast or how completely the packaging material might burn away to expose the magnesium
(3) Height and arrangement of the storage array
(4) Intensity of any exposure fire
(5) Rapidity with which automatic protection systems might respond to control the initial fire, thus preventing the involvement of the magnesium

The best method to determine the level of hazard is by a properly designed fire test.

A.7.7.7.4 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.7.8.2 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.7.8.3 Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, where they come into contact with water or residual moisture.

A.7.8.6 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A.7.8.8 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.7.8.13 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.8.1.1.3.1 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.8.1.1.3.3 Window ledges, girders, beams, and other horizontal projections or surfaces can have the tops sharply sloped, or other provisions can be made to minimize the deposit of dust thereon. Overhead steel I-beams or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning.

A.8.1.2.9 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.8.1.3.2 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.

Additionally, the risk of electrostatic discharge as a potential ignition source for niobium powders can be very high [minimum ignition energy (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.8.1.3.3 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.8.1.4.1 Electrical enclosures that are not purged and pressurized can become filled fully or partially with niobium dusts. Electrical classification and following the requirements of NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, can prevent this situation. However, in circumstances where a hazards analysis has concluded that a combustible dust cloud of niobium dust does not normally exist, and electrical enclosures are chosen not to be purged and pressurized, over time dust can still accumulate in electrical boxes. It is recommended that periodic inspections of electrical enclosures be conducted to ensure that the situation has not changed or that the original conclusions of the hazards analysis were incorrect.

A.8.1.4.3 Refer to NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A.8.1.4.4 See 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.

A.8.1.5.2 The design of deflagration venting should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.8.1.5.2.1 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 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.8.1.5.2.2 For further information on restraining vent closures, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.8.2.1 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 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.8.2.1.1 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 incorporating the changes in practice.

A.8.2.1.2.1 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.8.2.2.1 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.8.2.2.4 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.8.2.2.5 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.8.2.2.6 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.8.2.3 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.8.2.4.2 The collection of moisture in a mold could cause the niobium to react, causing a fire or explosion.

A.8.2.4.2.4 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.8.2.4.3 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.8.2.6 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.8.2.6.1 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.8.2.6.3.4 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.8.2.6.3.5 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.8.2.6.3.6 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.8.3 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.8.4.2 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.8.5.1 All but the coarsest niobium powders oxidize readily at temperatures above 80°C (176°F).

A.8.5.3 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.8.6 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.8.6.5 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.8.6.7(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.8.7.1 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.8.7.4 Refer to NFPA 77, *Recommended Practice on Static Electricity*.

A.8.7.7 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.8.8.1 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 condition
(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 belt or chain, encasement of the belt or chain in a practically dusttight enclosure constructed of substantial noncombustible material that should be maintained under positive air pressure

A.8.9.1 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*.

All associated equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

A.8.9.1.1(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.8.9.1.1(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.8.9.1.1(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.8.9.2 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.8.9.4.1 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.8.9.4.4 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.8.10 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 the processing methods used.

A.8.11.2 Proper grounding will assist in controlling static discharge, perhaps the most common source of ignition of dust clouds. A niobium dust cloud can ignite and explode from a static discharge of less than 3 mJ.

All joints on ducts conveying niobium dust should have a ground strap jumping the joint.

All equipment and associated ventilation or exhaust systems should be connected to a common ground.

Sometimes a good ground is difficult to obtain. The ground should be checked to ensure that it is a true ground. It is recommended that every ground location be checked on a regular basis (such as daily, weekly, or monthly), because ground connections tend to corrode and become brittle and break.

A.8.11.5 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.8.11.6 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.8.12 See the discussion under A.8.11.5.

A.8.12.7.1 Niobium compacts after furnacing might also require passivation.

A.8.12.8 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.8.13.1.2 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.

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.8.13.2.4 See A.8.13.1.2.

A.8.13.3 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 cake or a sponge-like deposit ("sludge"), which is highly combustible, on the inner wall of the exhaust duct.

A.8.13.3.6 See Figure A.6.3.4.4(a), Figure A.6.3.4.4(b), Figure A.6.3.4.4(c), and Figure A.9.7.3.6 for the major components of a typical liquid precipitator.

A.8.13.5 Dry dust collectors are not recommended for the collection of niobium.

A.8.13.5.4(B) All equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

A.8.13.5.5 The cyclone dust collector should be of conductive metal of suitable construction for the service intended and solidly 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 a process in which 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.8.13.8.3.3 If inert gas is used, the inert gas should be argon or helium. Nitrogen gas should not be used.

A.8.13.8.3.4.5 The design of deflagration venting should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.8.14.3.1 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.9.1.1.5 Window ledges, girders, beams, and other horizontal projections or surfaces can have the tops sharply sloped, or other provisions can be made to minimize the deposit of dust thereon. Overhead steel I-beams or similar structural shapes can be boxed with concrete or other noncombustible material to eliminate surfaces for dust accumulation. Surfaces should be as smooth as possible to minimize dust accumulations and to facilitate cleaning.

A.9.1.1.14 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.

A.9.1.2 Portable processing equipment should be constructed in a fashion so 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 ground. Additional attention should be placed on bonding portable equipment to eliminate the dangers of isolated conductors.

Additionally, the risk of electrostatic discharge as a potential ignition source for tantalum powders is very high [minimum ignition energy (MIE) less than 3 mJ]. Though theoretically possible, brush discharge from insulating materials has never been identified as an ignition source for tantalum 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 provides a means of further eliminating this potential danger. *(Refer to Annex B for additional information.)*

A.9.1.3.1 Refer to 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.

A.9.1.4.2 The design of deflagration venting should be based on information contained in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.9.1.4.2.1 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.9.1.4.2.2 For further information on restraining vent closures, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.9.1.4.3 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.9.2.1 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 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.9.2.1.1 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.9.2.1.3 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.9.2.1.5 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.9.2.1.6 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.9.2.1.7.2 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.9.2.1.8 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.9.2.2.1.1 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.9.2.2.2.2 The collection of moisture in the mold could cause the tantalum to react, causing a fire or explosion.

A.9.2.2.4 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 tantalum-melting furnace, or modification of an existing furnace.

A.9.2.2.5.1 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.9.3 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/s (110 ft/s), which puts it well ahead of the flame front, which travels at 1.2 m/s to 1.8 m/s (4 ft/s to 6 ft/s). 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 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 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.9.3.1.3.1 The principal fire hazard is the ease of ignition of finely divided combustible material with subsequent ignition of the less easily ignited particles.

A 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 tantalum fires. Materials used in mill operations should be evaluated for their susceptibility for ignition in a mill operations environment.

A.9.3.1.5 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.9.3.1.6 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.9.3.1.9 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.9.3.2 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.9.4.1.2 The quantity of tantalum powders stored in manufacturing operations and areas should be limited to that needed to continue the operation or process.

A.9.4.2 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.9.4.2.1 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.9.4.2.4.8 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.9.4.2.4.10 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.9.4.3.5 Refer to discussion under A.9.4.2.1.

A.9.4.4.3 Refer to NFPA 77, *Recommended Practice on Static Electricity.*

A.9.4.5.1 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.9.4.5.2(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.9.4.5.2(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.9.4.6 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.9.4.8.1 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.9.4.8.4 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.9.5.1.1 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.9.5.1.2 Proper grounding will assist in controlling static discharge, perhaps the most common source of ignition of dust clouds. A tantalum dust cloud can ignite and explode from a static discharge of less than 3 mJ.

All joints on ducts conveying tantalum dust should have a ground strap jumping the joint.

All equipment and associated ventilation or exhaust systems should be connected to a common ground.

Sometimes a good ground is difficult to obtain. The ground should be checked to ensure that it is a true ground. It is recommended that every ground location be checked on a regular basis (such as daily, weekly, or monthly), since ground connections tend to corrode and become brittle and break.

A.9.5.1.4 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. *(See A.9.4.8.1 for additional discussion on antistatic footwear.)*

A.9.5.1.5 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.9.5.1.6 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.9.5.3.1 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.9.5.4.1 See the discussion under A.9.4.2.1.

A.9.6.3 See A.9.5.3.1.

A.9.6.5 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.9.6.5.1 Tantalum compacts after furnacing might also require passivation.

A.9.7.1.2 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.9.7.2.4 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.9.7.2.6 For additional information, see NFPA 77, *Recommended Practice on Static Electricity.*

A.9.7.3.2 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 a manufacturer, seldom have properly sized venting to handle a combustible tantalum 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 the 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 finishing procedures are performed on these types of parts.

All equipment and all associated equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity.*

A.9.7.3.3 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 cake or a sponge-like deposit ("sludge"), which is highly combustible, on the inner wall of the exhaust duct.

A.9.7.3.6 See Figure A.6.3.4.4(a), Figure A.6.3.4.4(b), Figure A.6.3.4.4(c), and Figure A.9.7.3.6 for the major components of a typical liquid precipitator.

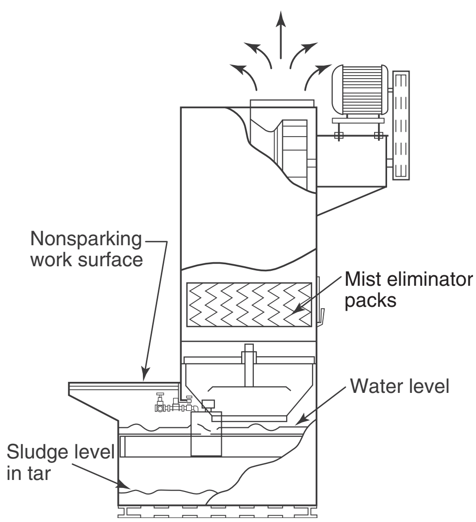


FIGURE A.9.7.3.6 Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

A.9.7.4 Dry dust collectors are not recommended for the collection of tantalum.

A.9.7.4.6 All equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

A.9.8.1.3 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.9.8.2.3 If inert gas is used, the inert gas should be argon or helium. Nitrogen gas should not be used.

A.9.8.3.3 For information on spacing and sizing of ductwork deflagration vents, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.9.8.3.3.2 NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, provides good engineering practice venting procedures. 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.9.9.3.1 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.9.10.1.1 See NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.9.10.3.2 An important prevention of fires and explosions is good housekeeping. Dust that accumulates on ledges, in cracks, in or over a ceiling, or on structural members will present a source of fuel for a secondary fire or explosion, which can be more severe than the initial fire or explosion. The following steps provide guidance on basic housekeeping measures that can be performed in this effort:

(1) Establish and maintain cleaning procedures to prevent accumulation of combustible dusts and fines.
(2) Eliminate rough surfaces and ledges where dust and fines might accumulate.
(3) Remove accumulations of dusts and fines with appropriate cleaning equipment.
(4) Where large quantities of dusts and fines are liberated at frequent intervals, use dust collection systems.
(5) Do not blow down dust accumulations with compressed air in open areas of the plant.
(6) Connect equipment exhaust ducts to a suitable collector.
(7) Operate equipment under a slightly negative pressure to prevent dust leakage outside the equipment.

A.9.10.3.3 Consideration should be given to the selection of tools when cleaning. Natural-bristle brushes have low static electricity accumulation compared to synthetic bristle brushes. Tools need to be of nonsparking material, such as phosphorous bronze.

A.9.10.3.5 There are many different types of vacuum systems, such as the following:

(1) Central
(2) Portable
(3) Wet
(4) Dry
(5) Cyclone
(6) Media filter
(7) Bag filter

Industry experience has demonstrated that dry collector systems have a high probability of explosion or fire occurring compared to wet collector systems. Seldom, if ever, has the source of ignition been positively identified. Knowing the potential for explosion, dry-type collectors should be located a safe distance from buildings [usually 15 m (50 ft) from other structures] and personnel. The area [usually a 15 m (50 ft) radius] should be secured and personnel clearly warned of the potential danger. Discharge from the system should be directed into an area that will not cause further contamination or risk to buildings or personnel in the event of a filter failure and the resulting dust discharge.

If a bag- or media-type collector is used, the shaking system or dust removal system should be designed to minimize sparking. Pneumatic- or pulse-type cleaning is the best method, because no mechanical moving parts are required in the dust-laden atmosphere. If a bag-type collector is used, antistatic bags or bags with ground wires, which can be positively grounded, are available. Where bag filters are used, the baghouse should be protected by an alarm system. The alarm system should respond to both excessive pressure drop across the bag filter and to high air temperature. Deflagration vents should be provided on the duct system, bag filter, and building in which the collector is housed as described in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

Sparking, friction, and impact should be minimized in the vacuum system design. The system should be designed by persons with knowledge of the risks and hazards of vacuum systems for handling metallic dusts. A high-efficiency wet collector system presents less hazard than dry-type collectors (which are prone to explosion or fire) by reducing the airborne dust to a wet slurry that is relatively safe.

The use of portable vacuums has been the source of several recorded fires. It is recommended that the use of portable vacuum cleaners be avoided or that they be used under very controlled conditions by qualified personnel. *(See* NFPA 77, *Recommended Practice on Static Electricity.)*

A.10.1.1.2 NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, contains information on the subject of explosion venting.

A.10.1.1.4 Floors should be slightly crowned to prevent accumulation of water in the vicinity of reduction furnaces.

A.10.1.2.4 For information on emergency gas shutoff valves, see NFPA 54, *National Fuel Gas Code*.

A.10.1.3.2 For information on guidelines for handling and storing chlorine, see the Chlorine Institute publication *The Chlorine Manual*.

A.10.1.3.3 Titanium tetrachloride in contact with moist air or water hydrolyzes to form hydrogen chloride gas and hydrochloric acid. Hydrogen chloride is toxic and highly irritating to the respiratory tract. If not immediately removed, titanium tetrachloride in contact with the eyes or skin will result in a double burn, one caused by the acid, the other caused by the heat of reaction. Any skin that is in contact with titanium tetrachloride should be wiped immediately and then flushed with a large amount of water. Eyes splashed with titanium tetrachloride also should be flushed with copious amounts of water.

A.10.1.4.3 A high-efficiency cyclone-type collector presents less hazard than a bag- or media-type collector and, except for extremely fine powders, usually operates 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 are some instances in which a centrifugal-type collector might 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 protected against. In each instance, the fan is 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 titanium fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances where 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. Because this practice presents a strong explosion potential, the bag- or media-type collector should be located a safe distance from buildings and personnel.

If a bag- or media-type collector is used, the shaking system or dust removal system should be designed to minimize sparking due to frictional contact or impact. Pneumatic- or pulse-type shaking is more desirable than systems that use mechanical moving parts, such as fan-driven systems, 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 that indicates excessive pressure drop across the bags. An excess air–temperature alarm is also frequently used.

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 bags are shaken. Explosion vents are usually built into the system, as described in NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.10.1.4.4 Information on spark-resistant fans and blowers can be found in AMCA 99-0401-86, "Classifications for Spark Resistant Construction."

A.10.1.5 Molten titanium and molten titanium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, if in contact with water or residual moisture.

A.10.2.1 Unlike other metals that can be melted, cast, or molded without unusual complications, titanium, because of its strong affinity for oxygen, hydrogen, and nitrogen and its tendency to become contaminated, is melted in special water-cooled or NaK-cooled copper crucibles under a vacuum or with an inert gas blanket of argon or helium. During the early years of the titanium industry, melting was done with a nonconsumable electrode, usually carbon.

The consumable electrode process using direct-current electricity was developed to meet quality and process requirements. Nonconsumable copper electrode furnaces are now being used to process scrap.

During the 1950s, several titanium-melting furnace explosions occurred when water inadvertently entered the melting crucibles during the melting operation. Three distinct types of explosions were evident: steam explosions produced by water contacting molten metal; chemical reaction between the molten metal and water; and explosion of free hydrogen generated by the chemical reaction. Also, if air entered the crucible at the same time, an air–hydrogen explosion would sometimes occur. All three types of explosions could occur in the same incident. The explosion hazard is present with any crucible that is water cooled.

The use of liquid metal NaK as a crucible coolant has been developed for both laboratory and commercial installations. While the danger of furnace explosion due to leakage into the melt zone is reduced, the handling of NaK has its own inherent hazards. The reaction between NaK and water is violent.

A.10.2.1.3 The explosion that can occur due to the rapid phase transformation of water trapped below molten material takes place over a time span of approximately 10^{-5} s to 10^{-4} s. This time span is faster than a condensed phase detonation. The required pressure-relief device would not be effective in safely relieving the rapid pressure buildup caused by the rapid phase transformation. It should be noted that the required pressure-relieving device is intended to safely relieve only much slower increases in pressure, such as might occur from small incursions of water onto the top of the molten metal.

A.10.2.2 The general process for shape casting of titanium is the "skull-casting" process, in which the material to be cast is melted as a consumable electrode in a tilting crucible. The power applied is normally somewhat higher than that typical for ingot melting, in order to develop a deep pool of molten metal. At the appropriate time in the melting cycle, the electrode is withdrawn and the casting poured. Vacuum or inert gas is provided to protect the metal from atmospheric contamination. The furnace crucible is made of copper and uses water or NaK as a coolant. Due to the high power levels used, seams in the crucible should not be exposed to the electric arc or the molten metal.

A.10.2.2.1 Titanium ingots contain internal stresses that can cause them to shatter, even up to several days after being wetted.

A.10.2.2.5 Personnel entering furnace shells to conduct inspections or repair work should first make certain that any inert gas has been purged from the shell and that all residue has been removed. Residues might be combustible or pyrophoric, and caution should be exercised.

A.10.3.1 Forging remains the most popular method of forming titanium, because it is generally simpler and less costly than other forming processes. Gas or electric furnaces with accurate heat control are used to heat the metal into the proper forging range, which can vary from 871°C to 1260°C (1600°F to 2300°F). The rate of heat-up and final temperature must often be controlled precisely to achieve specific metallurgical and physical properties. Slabs, billets, and bar stock are produced by forging.

Large rounds of titanium are produced by lathe turning or by grinding forges. A considerable amount of titanium strip, coil, and duct, down to foil thickness, is produced from slabs on both continuous and hand mills. Wide sheets and plates of various thicknesses are produced on hand mills or plate-rolling mills. Temperature control during rolling is important. Shearing and straightening operations are necessary to trim sheets and plates to size, to straighten or flatten plates, or to straighten forged bar stock or extrusions. Titanium wire is produced from coils of rolled bar by drawing operations. Fastener stock is produced from coils of wire. Titanium tubing is produced by inert gas seam welding of rolled narrow strip. Heavy wall seamless tubing is produced by extrusion.

Special types of grinding operations are performed in mills. Swing grinders are used to spot-grind ingots, slabs, billets, and bar stock. Centerless grinders are used to finish round bar and fastener stock. Strip, in coil form, is ground continuously, and sheets are individually ground.

Cold saws and abrasive cutoff saws are used to cut billet and bar stock to length. Swarf (finely divided metal particles) is produced by all sawing and grinding operations.

A.10.3.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.10.4.2.1 Improperly designed or dulled tools can produce high temperatures at the interface, causing ignition at the turnings, if an adequate coolant flow is not used.

A.10.4.2.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.10.4.4.1.2 Figure A.9.7.3.6, Figure A.10.4.4.1.2(a), Figure A.10.4.4.1.2(b), Figure A.6.3.4.4(a), and Figure A.6.3.4.4(c) illustrate precipitation collectors. These drawings are schematic and are intended only to indicate some of the features that are incorporated into the design of a separator. The volume of all dust-laden air space is as small as possible.

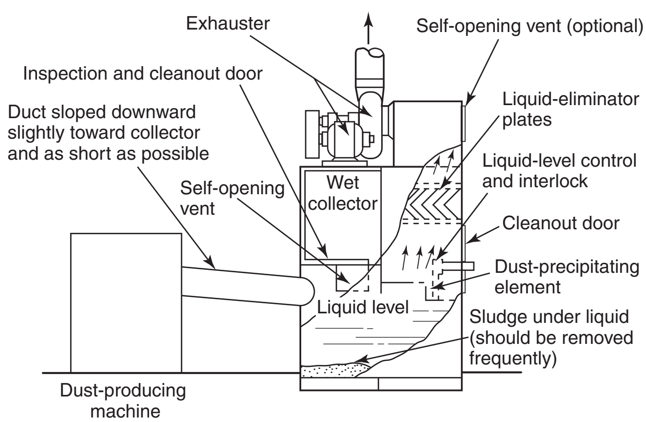


FIGURE A.10.4.4.1.2(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

A.10.4.4.4 For example, iron oxide dusts are known to be incompatible with titanium due to the potential for an exothermic reaction. The dust-separating unit should be cleaned, unless it has been determined that the materials exhibit no incompatibility. When a mixed-metal dust is produced from an operation on a single piece (i.e., a single part composed of steel and titanium), special consideration should be given to dust collection system cleanliness, including daily cleaning of ductwork, to preclude the possibility of an iron oxide buildup.

A.10.4.5.2 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.

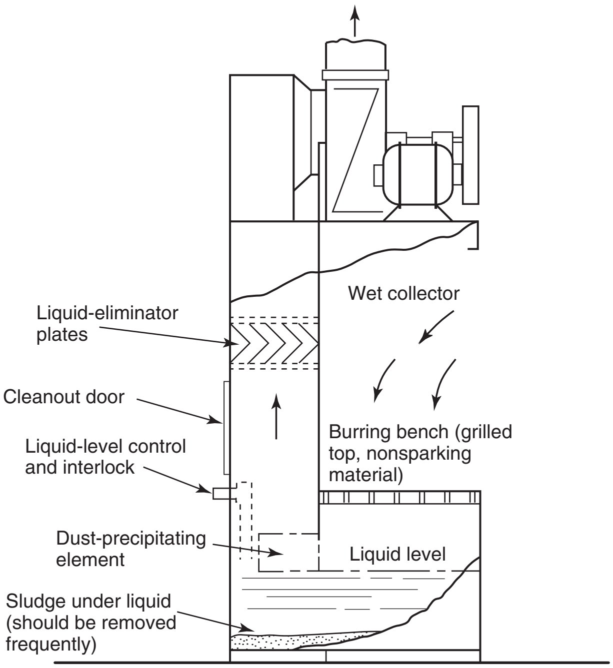


FIGURE A.10.4.4.1.2(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

A.10.4.6.4 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 removed more easily.

A.10.4.6.6 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.10.4.7.2 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 cake or a sponge-like deposit ("sludge"), which is highly combustible, on the inner wall of the exhaust duct.

A.10.4.8.7 Explosion venting is especially important for combustible titanium 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 titanium 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 the 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 finishing procedures are performed on these types of parts.

All equipment and all associated equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

A.10.5.1 Generation of titanium scrap from the sponge and melting processes through milling and fabrication is an inherent part of the titanium business. Scrap sponge, including some fines, is generated in the reduction, boring, crushing, leaching, and blending operations due to contamination and spills. Solid pieces of scrap titanium result from the melting process due to air or water contamination or to malfunctions that cause interrupted melts.

During milling and fabrication, solid pieces of scrap result from forge, welding, and fabrication shops. Other scrap includes lathe turnings and clippings.

Before recycling, lathe turnings and clippings are usually crushed and degreased with a water-soluble detergent. Solid scrap is more difficult to handle. In one process, large pieces are torch cut, then tumbled to remove slag, after which they are descaled in a basic chemical solution, washed in a sulfuric acid bath, and water rinsed. Hydrogenation and crushing completes the preparation for recycling. Another method of handling fairly large chunks of titanium scrap is to weld them to the sides of consumable electrodes prior to melting.

A more recent development is the nonconsumable electrode furnace for melting scrap into ingot form. Equipped with a continuous feed through a vacuum interlock, these furnaces are capable of handling scrap pieces of baseball size [chunks approximately 76 mm (3 in.) in diameter].

A.10.6.1 Not all methods of producing metal powder are applicable to titanium. Reduction of titanium hydride and some forms of milling generally are used to produce the limited amounts of powder now required commercially. To reduce oxidation and possible ignition hazards, milling can be performed under water or in an inert atmosphere of helium or argon. Some powders are given a very light copper coating during the manufacturing process.

Like many other metal powders, titanium is capable of forming explosive mixtures in air. The ignition temperatures of dust clouds, under laboratory test conditions, range from 330°C to 590°C (626°F to 1094°F). The MEC is 0.045 g/L (0.045 oz/ft^3). The maximum gauge pressure produced in explosions in a closed bomb at a concentration of 0.5 g/L (0.5 oz/ft^3) ranged from 317 kPa to 696 kPa (46 psi to 101 psi). The average rate of rise in gauge pressure in these tests ranged from 1724 kPa/s to 29,650 kPa/s (250 psi/s to 4300 psi/s); the maximum rate of rise in gauge pressure ranged from 3792 kPa/s to over 610,950 kPa/s (550 psi/s to over 10,000 psi/s).

The minimum energy of electrical condenser discharge sparks required for ignition of a dust cloud was 10 mJ (0.00239 calorie); for a dust layer, the minimum value was 10 μJ (0.000024 calorie). Some samples of titanium powder were ignited by electric sparks in pure carbon dioxide, as well as in air. In some cases, titanium at elevated temperatures was found to react in nitrogen as well as in carbon dioxide. Titanium powder is considered a flammable solid. *(See the NFPA Fire Protection Guide to Hazardous Materials.)*

A.10.6.1.2 Explosion venting systems should be designed according to NFPA 68, *Standard on Explosion Protection by Deflagration Venting*. Explosion venting drying rooms should be considered.

A.10.6.2.2.2 NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, can be used to determine good engineering practice.

A.10.6.2.3 The handling of dry titanium powder presents a fire and explosion hazard. The hazard increases as the size of the titanium particles decreases. The equipment and processes should be designed with consideration for the need to minimize the damage to property and risk to life resulting from fires and explosions involving titanium powder.

Design considerations should include the use of deflagration venting, proper dust collection systems, inerting, or a combination of those methods. The inert gas used should be determined by test to be appropriate for the titanium powder being handled. Titanium powder can react exothermically in pure carbon dioxide atmospheres and in pure nitrogen atmospheres.

Tests have shown that the maximum oxygen concentrations allowed for different inert gases to prevent explosions are as follows:

(1) Carbon dioxide — 0 percent oxygen
(2) Nitrogen — 6 percent oxygen
(3) Argon — 4 percent oxygen
(4) Helium — 10 percent oxygen

The data were obtained from U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders."

A.10.6.2.4 See 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.

A.10.7.3 Molten titanium and molten titanium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, if contacted with water or residual moisture.

A.10.7.10 See NFPA 77, *Recommended Practice on Static Electricity*.

A.11.1.2.2 NFPA 68, *Standard on Explosion Protection by Deflagration Venting*, contains information on the subject of deflagration venting.

A.11.1.2.4 Floors should be slightly crowned or drained to prevent the accumulation of water in the vicinity of reduction furnaces.

A.11.1.4.1 For information on guidelines for handling and storing chlorine, see the Chlorine Institute publication *The Chlorine Manual*.

A.11.1.4.3 Zirconium tetrachloride in contact with moist air or water hydrolyzes to form hydrogen chloride (HCl). Hydrogen chloride is toxic and highly irritating to the respiratory tract. If not immediately removed, zirconium tetrachloride in contact with the eyes or skin results in a double burn, one caused by the acid, the other caused by the heat of reaction. Any skin that comes in contact with zirconium tetrachloride should be wiped immediately and then flushed with a large amount of water. Eyes splashed with zirconium tetrachloride also should be flushed with copious amounts of water.

A.11.1.5.4 A high-efficiency cyclone-type collector presents less hazard than a bag-type or media-type collector and, except in the collection of extremely fine powders, usually operates 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 in some instances a centrifugal-type collector might be followed by a fabric- or bag-type 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 appropriate protection provided. In each instance, the fan is the last element downstream in the system. Because of the extreme hazard involved with a bag-type 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 explosion ultimately can be expected where a bag-type or media-type collector is used to collect zirconium fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances where it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag-type or media-type collector. Because this practice presents a strong explosion potential, the bag-type or media-type collector should be located a safe distance from buildings and personnel.

If a bag-type or media-type collector is used, the shaking system or dust-removal system can be such that it minimizes sparking due to frictional contact or impact. Pneumatic- or pulse-type shaking is recommended, 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, the baghouse should be protected by an alarm that indicates excessive pressure drop across the bags. An excess air–temperature alarm also is frequently used.

A bag-type or media-type collector should be located at least 15 m (50 ft) from any other building or operation. Personnel should not be permitted to be within 15 m (50 ft) of the collector during operation or when bags are being shaken. Deflagration vents usually are built into the system, in accordance with 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.11.1.5.5 Information on spark-resistant fans and blowers can be found in AMCA Standard 99-0401-86, "Classifications for Spark Resistant Construction."

A.11.1.6 Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, where they come into contact with water or residual moisture.

A.11.1.7.2 Wet zirconium sponge has the potential to generate hydrogen gas. Sealed covers have the potential to confine hazardous accumulations of hydrogen within the container.

A.11.2 Unlike other metals, which can be melted, cast, or molded without unusual complications, zirconium, because of its strong affinity for oxygen, hydrogen, and nitrogen and its tendency to become contaminated, is melted in special water- or sodium–potassium alloy (NaK)–cooled copper crucibles under a vacuum or with an inert gas blanket of argon or helium. During the early years of the zirconium industry, melting was done with a nonconsumable electrode, usually carbon.

The consumable electrode process using direct-current electricity was developed to meet quality and process specifications.

During the 1950s, several zirconium-melting furnace explosions occurred when water inadvertently entered the melting crucibles during the melting operation. Three distinct types of explosions were evident: steam explosions produced by water contacting molten metal; chemical reaction between the molten metal and water; and explosion of free hydrogen generated by the chemical reaction. Also, if air entered the crucible at the same time, an air–hydrogen explosion would sometimes occur. All three types of explosions could occur in a single incident. The explosion hazard is present with any crucible or electrode that is water cooled.

The use of liquid metal NaK as a crucible coolant has been developed for both laboratory and commercial installations. While the danger of furnace explosion due to leakage into the melt zone is reduced, the handling of NaK has its own inherent hazards. The reaction between NaK and water is violent.

A.11.2.1.3 The explosion that can occur due to the rapid phase transformation and dissociation reaction of water in contact with molten material takes place over a time span of approximately 10^{-5} s to 10^{-4} s. This time span is faster than a condensed phase detonation. The required pressure-relieving device is not effective in safely relieving the rapid pressure buildup caused by the rapid phase transformation. It should be noted that the required pressure-relieving device is intended to safely relieve only much slower increases in pressure, such as might occur from small incursions of water onto the top of the molten metal. Following a breech in the vacuum system, air enters the furnace, which could create a secondary explosion due to the presence of hydrogen generated by the molten metal–water reaction.

A.11.2.1.4 The use of a magnetic field to deflect the electric arc away from the crucible wall should be considered.

A.11.2.2 The general process for shape casting of zirconium is the "skull-casting" process, where the material to be cast is melted as a consumable electrode in a tilting crucible. The power applied is normally somewhat higher than typical for ingot melting in order to develop a deep pool of molten metal. At the appropriate time in the melting cycle, the electrode is withdrawn and the casting is poured. A vacuum or inert gas is provided to protect the metal from atmospheric contamination. The furnace crucible is made of copper and uses water or NaK for cooling. Because of the high power levels used, seams in the crucible should not be exposed to the electric arc or the molten metal.

A.11.2.2.5 Personnel entering furnace shells to conduct inspections or repair work should first make certain that any inert gas has been purged from the shell *(see 29 CFR, 1910.146, "Permit Required Confined Spaces")*. All combustible or pyrophoric residues should be removed or deactivated. Residues from casting furnaces are known to be combustible or pyrophoric, and caution should be exercised.

A.11.3 Forging remains the most popular method of forming zirconium because it is generally simpler and less costly than other forming processes. Gas or electric furnaces with accurate heat control are used to heat the metal to the proper forging range, which can vary from 871°C to 1260°C (1600°F to 2300°F). The rate of heat-up and final temperature often should be controlled precisely to achieve specific metallurgical and physical properties. Slabs, billets, and bar stock are produced by forging.

Large rounds of zirconium are produced by lathe turning or by grinding forges. A considerable amount of zirconium strip, coil, and sheet in thicknesses as thin as those of foil is produced from slabs on both continuous mills and hand mills. Wide sheets and plates of various thicknesses are produced on hand mills or plate-rolling mills. Temperature control during rolling is important. Shearing and straightening operations are necessary to trim sheets and plates to size, to straighten or flatten plates, or to straighten forged bar stock or extrusions. Zirconium wire is produced from coils of rolled bar by drawing operations. Fastener stock is produced from coils of wire. Zirconium tubing is produced by inert-gas seam welding of rolled narrow strip. Heavy-wall seamless tubing is produced by extrusion.

Special types of grinding operations are performed in mills. Swing grinders are used to spot-grind ingots, slabs, billets, and bar stock. Centerless grinders are used to finish round bar and fastener stock. Strip, in coil form, is ground continuously, and sheets are individually ground.

Cold saws and abrasive cut-off saws are used to cut billet and bar stock to length. Swarf (finely divided metal particles) is produced by all sawing and grinding operations.

A.11.3.1.2 See NFPA 77, *Recommended Practice on Static Electricity*, for operations where static electricity presents a hazard.

A.11.4.1.1 If a sufficient coolant flow is not used, improperly designed or dulled tools can produce high temperatures at the interface, causing ignition of the turnings.

A.11.4.2.2 Cleaning methodologies should consider the hazards of creating airborne dusts and the dangers associated with the use of vacuum cleaners.

A.11.4.3.1.2 See Figure A.6.3.4.4(a), Figure A.6.3.4.4(c), Figure A.9.7.3.6, Figure A.10.4.4.1.2(a), and Figure A.10.4.4.1.2(b) for typical dust collector drawings. These drawings are schematic and are intended only to illustrate some of the features that are incorporated into the design of a separator. The volume of all dust-laden air space is as small as possible.

A.11.4.3.4 For example, iron oxide dusts are known to be incompatible with zirconium due to the potential for an exothermic reaction. The dust-separating unit should be cleaned unless it has been determined that the materials exhibit no incompatibility.

A.11.4.3.7 Wet zirconium sludge has the potential to generate hydrogen gas. Sealed covers have the potential to confine hazardous accumulations of hydrogen within the container.

A.11.5 Generation of zirconium scrap from the sponge and melting processes through milling and fabrication is an inherent part of the zirconium business. Scrap sponge, including some fines, is generated in the reduction, boring, crushing, leaching, and blending operations due to contamination and spills. Solid pieces of scrap zirconium result from the melting process due to air or water contamination or due to malfunctions that cause interrupted melts.

During milling and fabrication, solid pieces of scrap result from forging, welding, and fabrication shops. Other scrap includes lathe turnings and clippings.

Before recycling, lathe turnings and chips are usually crushed, chopped, degreased, and compacted with a water-soluble detergent. Solid scrap is more difficult to handle. A method of handling fairly large chunks of zirconium scrap is to weld them to the sides of consumable electrodes prior to melting.

A more recent development is the nonconsumable electrode furnace for melting scrap into ingot form. Equipped with a continuous feed through a vacuum interlock, these furnaces are capable of handling scrap pieces of baseball size [chunks approximately 76 mm (3 in.) in diameter].

A.11.6 Not all methods of producing metal powder are applicable to zirconium. Reduction of zirconium hydride and some forms of milling are generally used to produce the limited amounts of powder now needed commercially. To reduce oxidation and possible ignition hazards, milling can be performed under water or in an inert atmosphere of helium or argon. Some powders are given a very light copper coating during the manufacturing process. See Figure A.6.3.4.4(a), Figure A.6.3.4.4(b), Figure A.6.3.4.4(c), and Figure A.10.4.4.1.2(b).

Like many other metal powders, zirconium is capable of forming explosive mixtures in air. The ignition temperatures of dust clouds, under laboratory test conditions, range from 330°C to 590°C (626°F to 1094°F). The MEC is 45 g/m^3 (0.045 oz/ft^3). The maximum gauge pressure produced in explosions in a closed bomb at a concentration of 0.5 kg/m^3 (0.5 oz/ft^3) ranged from 317 kPa to 558 kPa (46 psi to 81 psi). The average rate of gauge pressure rise in these tests ranged from 1724 kPa/s to 29,670 kPa/s (250 psi/s to 4300 psi/s). The maximum rate of pressure rise ranged from 3792 kPa/s to over 69,000 kPa/s (550 psi/s to over 10,000 psi/s). The minimum energy of electrical condenser discharge sparks necessary for ignition of a dust cloud was 10 mJ (0.00239 calorie). For a dust layer, the minimum value was 8 μJ (0.0000019 calorie). Some samples of zirconium powder were ignited by electric sparks in pure carbon dioxide, as well as in air. In some cases, zirconium at elevated temperatures was found to react in nitrogen as well as in carbon dioxide. Zirconium powder is considered a flammable solid.

A.11.6.1.1 Experience has shown that the tendency for autoignition increases with decreasing particle size of the powder. In particular, in the range of 40 μm and below, the particles exhibit pyrophoric tendencies. This tendency is exacerbated in the presence of moisture.

A.11.6.1.2 For information on designing deflagration venting, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.11.6.2.2 The equipment and processes should be designed with consideration for the need to minimize the damage to property and risk to life resulting from fires and explosions involving zirconium powder. Design considerations should include the use of deflagration venting, proper dust collection systems, inerting, or a combination of these. The inert gas used should be determined by test to be appropriate for the zirconium powder being handled. Zirconium powder can react exothermically in pure carbon dioxide atmospheres and in pure nitrogen atmospheres.

Tests have shown that, to prevent explosions, the limiting oxygen concentrations (LOCs) for the inert gases argon and helium are 4.0 percent and 5.0 percent, respectively. *(See* NFPA 69, *Standard on Explosion Prevention Systems, for further information on LOCs for safe handling of metal powders.)*

The test data were obtained from U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders," RI 4835, "Explosive Characteristics of Titanium, Zirconium, Thorium, Uranium, and Their Hydrides," and RI 6516, "Explosibility of Metal Powders."

A.11.6.2.4.2 See 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.

A.11.7.3 Molten magnesium and molten magnesium chloride present an extremely dangerous fire and fume hazard, in addition to an explosion hazard, where they come into contact with water or residual moisture.

A.11.7.5 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A.11.7.7 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.11.7.12 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.12.1.5 See NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.12.1.7.1 For information on deflagration venting, see NFPA 68, *Standard on Explosion Protection by Deflagration Venting*.

A.12.2.1.1 Minimum explosible concentrations (MECs) for combustible metal dust 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 exceed the MEC in the collector at the end of the system.

A.12.2.1.2 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.12.2.1.4.1 See Figure A.6.3.2.5.1.

A.12.2.1.5 Barriers or other protection should be provided because a high-efficiency cyclone-type collector presents less hazard than a bag- or media-type collector and, except for extremely fine powders, usually operates 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 centrifugal-type collector can be followed by a fabric- or bag-type 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 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 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 be such as to 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