

NFPA 484

Standard for Combustible Metals, Metal Powders, and Metal Dusts

2002 Edition



NFPA, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 484

Standard for

Combustible Metals, Metal Powders, and Metal Dusts

2002 Edition

This edition of NFPA 484, *Standard for Combustible Metals, Metal Powders, and Metal Dusts*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by NFPA at its May Association Technical Meeting held May 19–23, 2002, in Minneapolis, MN. It was issued by the Standards Council on July 19, 2002, with an effective date of August 8, 2002, and supersedes all previous editions of the standards listed in Origin and Development of NFPA 1984.

This edition of NFPA 484 was approved as an American National Standard on July 19, 2002.

Origin and Development of NFPA 484

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

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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.

This list represents the membership at the time the Committee was balloted on the final text of this edition. Since that time, changes in the membership may have occurred. A key to classifications is found at the back of the document.

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

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

A reference in brackets [] following a section or paragraph indicates material that has been extracted from another NFPA document. As an aid to the user, Annex I lists the complete title and edition of the source documents for both mandatory and nonmandatory extracts. Editorial changes to extracted material consist of revising references to an appropriate division in this document or the inclusion of the document number with the division number when the reference is to the original document. Requests for interpretations or revisions of extracted text shall be sent to the appropriate technical committee.

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

Chapter 1 Administration**1.1 Scope.**

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

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 and metal alloy parts and those materials, including scrap, that exhibit combustion characteristics of aluminum, lithium, 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 aluminum, lithium, magnesium, 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 metal.

1.1.7 This standard shall not apply to those laboratories covered by NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*.

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.

1.4 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.

1.4.3 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, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers*, 2002 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 2002 edition.

NFPA 30, *Flammable and Combustible Liquids Code*, 2000 edition.

NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*, 2000 edition.

NFPA 45, *Standard on Fire Protection for Laboratories Using Chemicals*, 2000 edition.

NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*, 1999 edition.

NFPA 54, *National Fuel Gas Code*, 2002 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 2002 edition.

NFPA 69, *Standard on Explosion Prevention Systems*, 2002 edition.

NFPA 70, *National Electrical Code*[®], 2002 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 2000 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1999 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1999 edition.

NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, 1999 edition.

NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*, 1999 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particulate Solids*, 1999 edition.

NFPA 101[®], *Life Safety Code*[®], 2000 edition.

NFPA 220, *Standard on Types of Building Construction*, 1999 edition.

NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*, 2000 edition.

NFPA 230, *Standard for the Fire Protection of Storage*, 1999 edition.

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 1998 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation*, 2002 edition.

NFPA 654, *Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids*, 2000 edition.

NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response*, 2001 edition.

NFPA 780, *Standard for the Installation of Lightning Protection Systems*, 2000 edition.

2.3 Other Publications.

2.3.1 ANSI Publication. American National Standards Institute, Inc., 11 West 42nd Street, 13th Floor, New York, NY 10036.

ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*, 1993 edition.

2.3.2 ASTM Publication. American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

2.3.3 U.S. Government Publication. U.S. Government Printing Office, Washington, DC 20402.

Title 49, *Code of Federal Regulations*, Parts 100–199, 1998.

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 included, common usage of the terms shall apply.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). The organization, office, or individual responsible 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. Potassium, sodium, lithium, calcium, rubidium, cesium, and alloys of these metals.

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 3.3.25.3.

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 3.3.21.2.

3.3.6* Combustible Metal Dust. Any finely divided metal 420 µm (microns) or smaller in diameter (that is, material passing a U.S. No. 40 standard sieve) that presents a fire or explosion hazard.

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. [68:3.3]

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. [654:1.5]

3.3.10 Duct. Pipes, tubes, or other enclosures used for the purpose of pneumatically conveying materials. [91:1.5]

3.3.11 Explosion. The bursting or rupture of an enclosure or a container due to the development of internal pressure from a deflagration. [69:3.3]

3.3.12 Fines.

3.3.12.1 Tantalum Ultra Fines. The fraction of a tantalum powder that will be 10 μm (microns) or smaller in nominal diameter, either as a discrete particle or as agglomerates of discrete particles.

3.3.12.2 Titanium or Zirconium Fines. Particles, typically 20 mesh and below, that can be ignited in a static layer.

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

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

3.3.15 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.

3.3.16* Heavy Casting. Castings greater than 11.3 kg (25 lb) with walls of large cross-sectional dimensions [at least 6.4 mm ($\frac{1}{4}$ in.)].

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

3.3.18* 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.

3.3.19 Magnesium Ribbon. Magnesium metal that is less than 3.2 mm ($\frac{1}{8}$ in.) in two dimensions or less than 1.3 mm ($\frac{1}{20}$ in.) in single dimension is considered a powder for the purposes of this standard.

3.3.20 Media Collector. A baghouse or a filter-type cartridge collector used for collecting dust.

3.3.21 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.

3.3.21.1 Alkali Metals. See 3.3.1.

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

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

3.3.23* 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.

3.3.24 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.

3.3.25 Powder.

3.3.25.1* Aluminum Flake Powder. See 3.3.25.3.

3.3.25.2 Aluminum Granular Powder. See 3.3.25.3.

3.3.25.3 Aluminum Powder. Aluminum powder is divided into three broad classifications: atomized, flake, and granules. 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 particle is several hundred times its thickness. Granules are generally powders larger than 75 μm (microns) (200 mesh).

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

3.3.25.5 Tantalum Powder. Nodular or flake-like tantalum particles that will pass through a 20-mesh screen as discrete particles or as agglomerates of discrete particles.

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

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

3.3.27* Pyrophoric Material. A substance capable of self-ignition on short exposure to air under ordinary atmospheric conditions.

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

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

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

3.3.31 Spontaneous Heating. Slow oxidation of an element or compound that causes the bulk temperature of the element and compound, or the element or compound, to rise without the addition of an external heat source.

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

3.3.33 Tantalum Powder. See 3.3.25.5.

3.3.34 Tantalum Ultra Fines. See 3.3.12.1.

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

3.3.36 Titanium or Zirconium Fines. See 3.3.12.2.

Chapter 4 Aluminum

4.1 Aluminum Powder Production Plants.

4.1.1 Location.

4.1.1.1 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.

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

4.1.2 Building Construction.

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

4.1.2.2 The buildings specified in 4.1.2.1 shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

4.1.2.3 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.

4.1.2.4 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

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

4.1.2.6 The requirements of 4.1.2.5 shall also apply to elevated platforms, balconies, floors, or gratings.

4.1.2.7 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.

4.1.2.8 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.

4.1.2.9 Roof decks and basements shall be watertight.

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

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

4.1.3 Door and Window Construction.

4.1.3.1 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 Fire Windows*.

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

4.1.4 Enclosed Passageways.

4.1.4.1* 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.

4.1.4.2 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*.

4.1.5 Grounding and Lightning Protection.

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

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

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

4.1.6 Electrical Power and Control.

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

4.1.6.2* Powder-manufacturing areas shall be classified, where applicable, in accordance with Article 500 of NFPA 70, *National Electrical Code*.

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

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

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

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

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

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

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

4.1.7 Heating and Cooling of Aluminum Powder Production Buildings.

4.1.7.1 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.

4.1.7.2 Indirect hot air shall be permitted if the heating unit is located in a combustible aluminum dust-free area adjacent to the room or area where heated air is required.

4.1.7.3 Fans or blowers used to convey the heated or cooled air shall also be located in a combustible aluminum dust-free location.

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

4.1.7.5 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 aluminum dust or powder.

4.1.7.6 The requirements of 4.1.7.1 through 4.1.7.5 shall not apply to areas where aluminum metal is melted.

4.1.8 Machinery and Operations.

4.1.8.1 General Precautions. The precautions of 4.1.8.1.1 through 4.1.8.1.3 shall apply to new and existing facilities where aluminum powder is produced or handled.

4.1.8.1.1 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, or impact, such as iron or steel articles on stones, on each other, or on concrete, or other energy sources.

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

4.1.8.1.3* 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.

4.1.8.2 Requirements for Machinery.

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

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

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

4.1.8.2.4 Bearings.

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

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

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

4.1.8.2.6 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.

4.1.8.3 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.

4.1.9 Handling and Conveying of Aluminum Powder.

4.1.9.1 Where aluminum powder is present, good house-keeping practices shall be maintained.

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

4.1.9.3 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.

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

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

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

4.1.9.7 Portable Containers.

4.1.9.7.1 Transport of aluminum powders shall be done in covered conductive containers as described in 4.1.9.4.

4.1.9.7.2 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 Operation*.

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

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

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

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

4.1.9.8.4 A minimum conveying velocity of 1364 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.

4.1.9.8.5* 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.

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

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

4.1.9.8.6.2 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.

4.1.9.8.7 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 pressure of at least 690 kPag (100 psig).

4.1.9.8.8 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.

4.1.9.9 Conveying Using an Inert Medium.

4.1.9.9.1* Inert gas-conveying systems shall be permitted, if designed in accordance with Chapter 2 of NFPA 69, *Standard on Explosion Prevention Systems*.

4.1.9.9.2* 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.

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

4.1.9.9.4 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.

4.1.9.9.5 A minimum conveying velocity of 1364 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.

4.1.9.9.6 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.

4.1.9.10 Fan and Blower Construction and Arrangement.

4.1.9.10.1* 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.

4.1.9.10.2 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.

4.1.9.10.3 Personnel shall not be permitted within 15 m (50 ft) of the fan or blower while it is operating.

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

4.1.9.10.3.2 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.

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

4.1.9.10.4* 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.

4.1.9.10.5* 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.

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

4.1.10 Powder Collection.

4.1.10.1* Collectors.

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

4.1.10.1.2* 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.

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

4.1.10.1.4 Ductwork shall comply with the provisions of 4.1.9.8.

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

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

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

4.1.10.1.7.1 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.

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

4.1.10.1.8 Repairs.

4.1.10.1.8.1 Where repairs on dry dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed. (*See 4.4.2.*)

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

4.1.10.2 High-Temperature Warning.

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

4.1.10.2.2 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.

4.1.10.2.3 The devices specified in 4.1.10.2.2 shall give audible and visual alarms at normally attended locations.

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

4.1.11 Storage of Aluminum Powder. When aluminum powder is stored in sealed containers, the procedures of 4.1.11.1 through 4.1.11.7 shall apply.

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

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

4.1.11.3 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 other construction types protected with an automatic sprinkler system.

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

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

4.1.11.5.1 Stacked storage shall be arranged to ensure stability.

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

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

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

4.2 Aluminum Powder Handling and Use.

4.2.1 Scope. The provisions of Section 4.2 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.

4.2.2 Storage. Dry aluminum powder and aluminum paste shall be stored in accordance with the provisions of 4.1.11.

4.2.3* Handling. The requirements of Section 4.2 shall apply to both regular and “nondusting” grades of aluminum powder, as well as aluminum paste.

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

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

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

4.2.3.4 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 Operation*.

4.2.4 Machinery and Operations.

4.2.4.1* Wet Milling of Aluminum Powder. The requirements of 4.2.4.1.1 through 4.2.4.1.6 shall not apply to machining and rolling operations.

4.2.4.1.1* 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.

4.2.4.1.2* 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.

4.2.4.1.3 The dew point of the atmospheres in 4.2.4.1.1 and 4.2.4.1.2 shall be maintained below the point where condensation occurs.

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

4.2.4.1.5* 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.

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

4.2.4.2 Electrical Equipment.

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

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

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

4.2.4.2.4* 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*.

4.2.4.3 Plasma Spray Operations.

4.2.4.3.1 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.

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

4.2.5* 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, or buildings from the fire or dust explosion hazard produced by airborne suspensions of combustible aluminum dusts or powders.

4.2.6 Prevention of Fugitive Dust Accumulations. See Section 4.4.

4.3 Processing and Finishing Operations.

4.3.1* Scope.

4.3.1.1 Section 4.3 shall apply to operations where aluminum or aluminum alloys are subjected to processing or finishing operations.

4.3.1.2 The operations specified in 4.3.1.1 shall include, but shall not be limited to, grinding, buffing, polishing, sawing, and machining of solids.

4.3.2 Dust-Producing Operations.

4.3.2.1* 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.

4.3.2.2 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.

4.3.2.3* 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.

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

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

4.3.2.5.1* 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 4.3.2.5.1(A) through 4.3.2.5.1(D).

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

(B) Personnel protective clothing shall comply with 4.6.2.

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

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

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

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

CAUTION: This dust collector can contain explosible dust.

4.3.2.6* Dust-collection systems shall be dedicated to collection of aluminum or aluminum alloy dust only.

4.3.2.6.1 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.

4.3.2.6.2 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.

4.3.3 Dust-Collection Ducts and Ductwork.

4.3.3.1 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*.

4.3.3.2 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).

4.3.3.3* Ducts shall be designed to handle a volumetric flow rate that maintains dust loading safely below the minimum explosible concentration (MEC).

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

4.3.3.5 Duct Construction.

4.3.3.5.1 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.

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

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

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

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

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

4.3.4 Wet-Type Dust Collectors.

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

4.3.4.1.1 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.

4.3.4.1.2 The cleaned air shall be permitted to be returned to the work area where tests conducted by an approved testing organization prove 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. (See 4.5.2.1.)

4.3.4.2* 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.

4.3.4.3 Location of Dust Collector.

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

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

4.3.4.4* 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.

4.3.4.5* Collector Sludge.

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

4.3.4.5.2 Sludge shall be disposed of in accordance with the requirements of 4.3.4.8.

4.3.4.6 Collector Sump Venting.

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

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

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

4.3.4.7 Power Supply.

4.3.4.7.1 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.

4.3.4.7.2 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.

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

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

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

4.3.4.8.3 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.

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

4.3.5 Dry-Type Dust Collectors.

4.3.5.1 Electrostatic collectors shall not be used.

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

4.3.5.3 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.

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

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

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

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

4.3.5.5.3 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.

4.3.5.6* 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.

4.3.5.7 Where repairs on dry dust collectors are necessary, the collectors shall be emptied and residual accumulations of

dust thoroughly removed (*see* 4.4.2). Ductwork leading into the collector shall be disconnected and blanked off before repair work shall be permitted to be started.

4.3.5.8 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.

4.3.5.9 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.

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

4.3.7 Machining and Sawing Operations.

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

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

4.3.7.3 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.

4.3.7.4 Coolant.

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

4.3.7.4.2 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.

4.3.8 Electrical Equipment.

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

4.3.8.2* Bonding and Grounding.

4.3.8.2.1 All components of the dust-collection systems shall be electrically bonded and grounded.

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

4.4 Housekeeping.

4.4.1 Scope. Section 4.4 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

4.4.2 Cleanup Procedures for Fugitive Dust Accumulations.

4.4.2.1* Fugitive dust shall not be allowed to accumulate.

4.4.2.2 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 4.4.3

4.4.2.3 Cleanup of Spilled Aluminum Powder.

4.4.2.3.1 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.

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

4.4.3* Vacuum-Cleaning Systems.

4.4.3.1 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.

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

4.4.3.3 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.

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

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

4.4.3.5.1 Assembled components shall be conductive and bonded where necessary.

4.4.3.5.2 Periodic tests for continuity shall be performed.

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

4.4.4 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.

4.4.5 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.

4.4.6 Cleaning Frequency.

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

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

4.5 Fire Prevention, Protection, and Procedures.

4.5.1* Scope. Section 4.5 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

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

4.5.2.1* 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.

4.5.2.2 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.

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

4.5.2.4* 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.

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

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

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

4.5.2.6.2 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."

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

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

(B) Halogenated extinguishing agents shall not be used.

4.5.3* Solvent-Wetted Powders.

4.5.3.1 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.

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

4.5.3.3 Carbon Dioxide Use.

4.5.3.3.1* 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.

4.5.3.3.2 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.

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

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

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

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

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

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

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

4.5.3.4.6* Fire flow containment shall be provided for new facilities.

4.5.4 Automatic Sprinkler Protection.

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

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

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

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

4.5.4.3 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, and, where applicable, NFPA 230, *Standard for the Protection of Storage*.

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

4.5.5 Fire-Fighting Organization.

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

4.5.5.1.1 All other personnel shall be evacuated from the area.

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

4.5.5.2 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.

4.5.5.3* 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.

4.5.6* 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.

4.5.7 Control of Ignition Sources.

4.5.7.1 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.

(A) 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.

(B) Lockout/tagout procedures shall be followed for the shutdown of machinery.

(C) 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*.

4.5.7.2 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.

4.5.7.3* 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.

4.5.7.4 Nonsparking tools shall be used when making repairs or adjustments on or around any machinery or apparatus where combustible aluminum dust is present.

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

4.5.7.6 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*.

4.5.7.7 Cleaning Tools.

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

4.5.7.7.2 Synthetic bristles shall not be used.

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

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

4.5.8 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.

4.6 Safety Procedures.

4.6.1 Scope. Section 4.6 shall apply to new and existing facilities where combustible aluminum dusts, pastes, and powders are present.

4.6.2 Personal Protective Equipment.

4.6.2.1 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.

4.6.2.2 Work clothing shall be designed to minimize the accumulations of combustible aluminum dust (for example, trousers shall not have cuffs).

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

4.6.2.4* Clothing Fires.

4.6.2.4.1 Emergency procedures for handling clothing fires shall be established.

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

4.6.3 Emergency Procedures.

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

4.6.3.2* All employees shall be trained in the emergency procedures specified in 4.6.3.1.

4.6.4 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.

4.6.5 Maintenance. Regular and periodic maintenance checks and calibration on equipment critical to employee safety and plant operation shall be performed.

Chapter 5 Lithium

5.1* General Precautions.

5.1.1* Special Considerations. Lithium shall be kept away from sources of moisture.

5.1.2* Handling, Processing, and Storage Areas for Lithium.

5.1.2.1 Lithium 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 Lithium handling, processing, and storage areas shall have diamond markings on the exterior 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* Lithium Fire Residue.

5.1.3.1* Lithium fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

5.1.3.2 Lithium fire residues shall be disposed of in accordance with federal, state, and local regulations.

5.1.3.3 Containers of lithium fire residue shall be inspected and the results recorded monthly by individuals who are trained in the hazards of lithium and able to recognize potential problems associated with these containers.

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 or storage of solid or molten lithium.

5.2.1.2 Noncombustible Materials.

5.2.1.2.1 Buildings dedicated to the storage, handling, processing, or use of lithium 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 solid lithium is stored, handled, or processed, floors shall be a solid surface and shall be constructed with materials that are compatible and nonreactive with, and capable of providing containment of, the molten lithium resulting from fire.

5.2.1.7 Where gratings are used or lithium is handled overhead, accessibility to the area below shall be restricted.

5.2.1.8 Floor drains shall not be permitted.

5.2.1.9 Where molten lithium is handled, dispensed, or stored, the handling area shall be provided with compatible and nonreactive containment.

(A) 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.

(B) In areas where molten lithium is handled, wall-to-floor connections shall be sealed against the penetration of molten lithium.

5.2.1.10 All electrical equipment and wiring shall comply with NFPA 70, *National Electrical Code*.

5.2.2 Separation from Water.

5.2.2.1* Water pipes or pipes that can contain water under normal use (for example, domestic water pipes, roof drains, waste pipes) shall not be permitted in areas containing lithium.

5.2.2.2 A sprinkler system(s) deemed appropriate per 5.5.1.4 shall be permitted.

5.2.2.3 Portions of buildings where lithium is stored, handled, processed, or used shall be separated by watertight walls, ceilings, and door systems from adjacent areas not handling or storing lithium where water can be present.

5.2.2.4 The floor shall be sloped away from the entrance to areas where lithium is stored, handled, or processed, or other means shall be taken to prevent the entrance of water.

5.3 Handling or Processing of Solid or Molten Lithium.

5.3.1 General Precautions.

5.3.1.1 Lithium shall be handled only by trained personnel who are knowledgeable of the hazards associated with lithium.

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

5.3.1.3 Access to lithium-handling areas by unauthorized personnel shall not be permitted.

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

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

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

5.3.1.7* Allowable Quantity.

5.3.1.7.1 The quantity of lithium permitted in processing areas shall be limited to that necessary for operations, but it shall not exceed the quantity required in one shift.

5.3.1.7.2 Melting/casting operations shall be permitted to maintain more than one shift's supply of lithium in process vessels, or in drums in which lithium would be melted, with appropriate protection, across one or more shifts.

5.3.2 Solid Lithium Handling.

5.3.2.1* Where lithium is processed with a flammable or combustible liquid, it shall be handled in accordance with NFPA 30, *Flammable and Combustible Liquids Code*.

5.3.2.2 Solid lithium shall be protected from moisture during handling by water-free mineral oil or by the use of dry air [air having a maximum of 0.314 mg of water per gram of air (2.2 grains of water per pound of air)], argon, helium, or other protective methods.

(A) Lithium shall be permitted to be exposed to non-dry air when being transferred from clean, moisture-free, sealed metal portable containers dedicated to the handling of solid lithium to process vessels, when inert atmospheres for the

lithium are not feasible and oil coating is inappropriate for the process.

(B) If left open for more than 15 minutes, the portable container shall be purged with a gas that is inert to lithium.

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

5.3.2.4 Surplus lithium shall be returned to an approved container and resealed immediately in accordance with 5.3.2.2.

5.3.3 Molten Lithium Handling.

5.3.3.1 Molten lithium shall be contained in closed systems that prevent its contact with air or reactive materials, except as required for the process.

5.3.3.2 Molten lithium piping systems shall be designed in conformance with ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*. All pump seals and flange gaskets shall be made of compatible materials.

5.3.3.3* Molten lithium 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 and iron oxide.

5.3.3.4 Molten lithium shall be handled in a detached building or in portions of a building separated from other exposures by barrier walls so any fire can be dealt with as a lithium fire.

5.3.3.5 Where molten lithium is cast, molds, ladles, and other components that could come in contact with the molten lithium shall be free of incompatible materials, including moisture and iron oxide.

5.4 Storage of Solid or Molten Lithium.

5.4.1 General Precautions.

5.4.1.1* Lithium shall be permitted to be stored in shipping containers meeting the requirements of 49 CFR, 100-199 or in clean, moisture-free, compatible and nonreactive metal sealed containers dedicated for the storage of lithium.

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

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

5.4.1.4 Lithium containers shall not be stored outside, except that lithium fire residues shall be permitted to be stored outside where placed in a double-steel, overpack drum and inspected daily.

5.4.2 Solid Lithium Storage.

5.4.2.1 Solid lithium shall be stored only on the ground floor.

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

5.4.2.3 The solid lithium storage area shall be isolated from other areas so that water cannot enter by spray or drainage from automatic sprinkler systems or any other water source.

5.4.2.4 Container Storage Arrangement.

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

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

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

5.4.2.4.4 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.

5.4.2.4.5 Idle pallet storage shall not be permitted in solid lithium storage areas.

5.4.3 Molten Lithium Storage. Molten lithium storage shall be in closed systems and in separate buildings or portions of buildings designed solely for that purpose by competent designers.

5.5 Fire Protection.

5.5.1* General Precautions.

5.5.1.1 A fire protection plan shall be provided for all areas where lithium is processed, handled, used, and stored.

5.5.1.2* Buildings or portions of buildings in which the only combustible hazard present is lithium shall not be permitted to be equipped with sprinkler protection.

5.5.1.3* Buildings or portions of buildings that have combustible hazards in addition to lithium shall be evaluated for fire protection requirements with a process hazard analysis that is acceptable to the authority having jurisdiction.

5.5.1.4 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted in areas where combustibles other than lithium create a more severe fire hazard than the lithium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with lithium.

5.5.1.5* As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the lithium operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

5.5.1.6 Prior to the arrival of lithium on-site, the local fire department shall be notified of the presence of water-reactive materials, lithium in particular, on-site, and shall be notified of the hazards of using water on lithium fires.

5.5.2 Extinguishing Agents and Application Techniques.

5.5.2.1* Only listed, Class D extinguishing agents or those tested and shown to be effective for extinguishing lithium fires shall be permitted.

(A) A supply of extinguishing agent for manual application shall be kept within easy reach of personnel working with lithium.

(B) The amount of extinguishing agent to be provided shall follow the listing agency's or manufacturer's recommendations.

5.5.2.2 Extinguishing Agent Containers.

5.5.2.2.1 Extinguishing agents intended for manual application shall be kept in their original, labeled factory containers.

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

5.5.2.2.3 Where large quantities of extinguishing agent are expected to be needed, a clean, dry shovel shall be provided with the container.

5.5.2.2.4 Where small amounts of extinguishing agent are needed, a hand scoop shall be provided with each container.

5.5.2.3* Portable or wheeled extinguishers listed for use on lithium fires shall be permitted and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

5.5.2.4 The following agents shall not be used as extinguishing agents on a lithium fire because of adverse reaction (*see Annex H*):

- (1) Water
- (2) Foams
- (3) Halon
- (4) Carbon dioxide
- (5) Nitrogen

5.5.2.5* An A:B:C dry-chemical extinguisher or a B:C dry-chemical extinguisher shall not be used as a lithium fire-extinguishing agent but shall be permitted to be used on other classes of fires in the area where lithium is present.

5.5.2.6* Fire-extinguishing agent expellant gases shall be compatible with lithium.

5.5.3 Personal Protective Equipment for Fire Fighting.

5.5.3.1* Proper protective clothing, respiratory protection, and adequate eye protection shall be used by all responding fire-fighting personnel assigned to a lithium fire.

5.5.3.2* Additional eye protection, equivalent to a No. 6 welding lens, shall be worn by personnel wearing self-contained breathing apparatus (SCBA) to protect against the brighter than ambient light emitted during a lithium fire.

5.5.4 Protective Equipment for Facility Personnel Performing Incipient-Stage Lithium Fire Fighting.

5.5.4.1 If incipient-stage lithium fires are to be fought, personal protective equipment shall be worn.

- (1) Personal protective equipment shall include face shields, head protection, gloves, external clothing, and respiratory protection.
- (2) Personnel shall be trained in the special hazards of lithium fires prior to fighting a lithium fire.

5.5.4.1.1* Personnel who attempt to fight a lithium fire in its incipient stage shall, as a minimum, wear full face shields.

5.5.4.1.2 Head protection shall consist of hard hats.

5.5.4.1.3 Gloves shall conform with 5.6.2.3.

5.5.4.1.4 If provided, external clothing shall conform with 5.6.2.5.

5.5.4.1.5 Respiratory protection suitable for the hazards of lithium shall be provided.

5.5.4.2 If incipient-stage lithium fires are to be fought, personal protective equipment shall be readily accessible and maintained in good condition in all areas where lithium is handled.

5.5.4.3 A minimum of two sets of personal protective equipment shall be provided if incipient-stage lithium fires are to be fought.

5.5.5 Lithium Fire-Fighting Procedures.

5.5.5.1* While a lithium fire is being fought, every effort shall be made to avoid splattering the burning lithium.

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

5.6 Personal Protective Equipment for Molten Lithium- and Solid Lithium-Handling Operations.

5.6.1* Personal Protective Equipment for Solid Lithium Handling.

5.6.1.1 Eye protection shall be worn while handling solid lithium.

5.6.1.2 Gloves shall be worn while handling solid lithium.

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 while handling solid lithium shall have no exposed pockets or cuffs that could trap and carry lithium residues.

5.6.2* Personal Protective Equipment for Handling Molten Lithium.

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

5.6.2.2 While handling molten lithium, safety glasses and full-face protection shall be worn, that is, face shields.

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

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

5.6.2.5* An external clothing layer, 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 lithium.

Chapter 6 Magnesium

6.1 Location and Construction of Magnesium Powder Production Plants.

6.1.1 Location.

6.1.1.1 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.

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

6.1.1.3 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 nonload-bearing, noncombustible, and without openings.

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

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

6.1.2 Security.

6.1.2.1 Application.

6.1.2.1.1 Subsection 6.1.2 shall apply to new and existing magnesium powder production plants.

6.1.2.1.2 The intent of 6.1.2 shall be to restrict access by the general public to magnesium powder production plants and to establish adequate exit facilities for personnel.

6.1.2.2 The powder production plant shall be surrounded by strong fencing at least 1.8 m (6 ft) high with suitable entrance gates or shall be otherwise rendered inaccessible.

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

6.1.3 Building Construction.

6.1.3.1 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 non-combustible materials throughout, and shall have nonload-bearing walls.

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

6.1.3.1.2 Construction of other than combustible materials shall be permitted if equivalent protection can be demonstrated.

6.1.3.2 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.

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

6.1.3.4 The requirements of 6.1.3.3 shall also apply to elevated platforms, balconies, floors, or gratings.

6.1.3.5 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.

6.1.3.6 Roof decks shall be watertight.

6.1.4 Doors and Windows.

6.1.4.1 All exits shall conform with NFPA 101, *Life Safety Code*.

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

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

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

6.1.6 Electrical Power.

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

6.1.6.2* All parts of manufacturing buildings shall be classified.

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

6.1.6.3.1 The emergency lighting shall be energized automatically upon loss of electrical power to the buildings.

6.1.6.3.2 Buildings of less than 19 m² (200 ft²) that are not normally occupied shall not be required to have emergency lighting systems.

6.2 Magnesium Mill and Foundry Operations.

6.2.1* Melting and Casting Operations.

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

6.2.1.1.1 Melt rooms shall provide access to facilitate fire control.

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

6.2.1.2* 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.

6.2.1.3 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.

6.2.1.4* Prevention of Molten Magnesium Contact with Foreign Materials.

6.2.1.4.1 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.

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

6.2.1.4.3 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.

6.2.1.4.4 Melting pots and crucibles shall be inspected regularly.

6.2.1.4.5 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.

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

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

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

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

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

6.2.2* Heat Treating.

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

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

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

6.2.2.4 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 slightly above the desired operating temperature.

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

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

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

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

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

6.2.2.10* 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.

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

6.3 Machining, Finishing, and Fabrication of Magnesium.

6.3.1* Machining.

6.3.1.1 Cutting tools shall not be permitted to ride on the metal without cutting, as 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.

6.3.1.2* 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.

6.3.1.3 Relief shall be maintained on tools used in grooving and parting operations, since 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.

6.3.1.4 If lubrication is needed, as in tapping or extremely fine grooving, a high-flash point mineral oil shall be used.

6.3.1.4.1 Water, water-soluble oils, and oils containing more than 0.2 percent fatty acids shall not be used, as they can generate flammable hydrogen gas.

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

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

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

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

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

6.3.1.6.3 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 6.7.

6.3.1.6.4 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.

6.3.2 Dust Collection.

6.3.2.1 Hoods.

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

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

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

6.3.2.3 The use of dry media-type collectors shall be prohibited.

6.3.2.4 Wet-Type Dust Collectors.

6.3.2.4.1* 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.

6.3.2.4.2* Wet-type dust collectors shall be restricted to a dust-loading of no more than 175 gr/m³ (5 gr/ft³) of inlet air on standard configuration collectors.

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

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

6.3.2.4.5 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.

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

6.3.2.4.7 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.

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

6.3.2.4.9 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.

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

6.3.2.5 Cyclone Dust Collectors.

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

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

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

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

6.3.2.5.5 The minimum length of duct from the dust-producing operation(s) to the cyclone shall be 4.6 m (15 ft).

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

6.3.2.6 Ductwork.

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

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

6.3.2.6.3 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).

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

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

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

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

6.3.2.6.8 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*.

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

6.3.2.6.10 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.

6.3.2.6.11 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.

6.3.3 Cleaning.

6.3.3.1 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.

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

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

6.3.4 Electrical Equipment.

6.3.4.1* Dust-producing machines, including areas containing dust-collection equipment, shall be classified in accordance with Article 500 of NFPA 70, *National Electrical Code*.

6.3.4.2 All electrical equipment shall be inspected and cleaned periodically.

6.3.4.3 Where flashlights or storage battery-operated lanterns are used, they shall be listed for classified locations.

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

6.3.6 Safety Precautions.

6.3.6.1 Operator clothing shall be flame retardant, 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.

6.3.6.2 Machinery and equipment described in 6.4.2 shall not be used for processing other metals until the entire grinder and dust-collection system are thoroughly cleaned, and the grinding wheel or belt shall be replaced prior to work on other metals.

6.3.6.3* 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.

6.3.6.3.1 In areas where the type of work specified in 6.3.6.3 is done, all machinery shall be shut down, and the area shall be thoroughly cleaned to remove all accumulations of magnesium dust.

6.3.6.3.2 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.

6.3.6.3.3 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*.

6.3.6.4* Grinding Wheels.

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

6.3.6.4.2 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.

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

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

6.3.7 Drawing, Spinning, and Stamping.

6.3.7.1 Reliable means to prevent overheating shall be provided where heating magnesium for drawing or spinning.

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

6.3.7.3 Fine particles shall be handled according to the requirements of Section 6.4.

6.4 Magnesium Powder — Machinery and Operations.

6.4.1 General Precautions.

6.4.1.1 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 (for example, iron or steel articles on stones, on each other, or on concrete).

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

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

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

6.4.2 Requirements for Machinery.

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

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

6.4.2.2.1 The requirement of 6.4.2.2 shall apply to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled.

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

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

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

6.4.2.5 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.

6.4.3 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.

6.4.4 Charging and Discharging.

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

6.4.4.2 Where charging magnesium powders to (or discharging from) machines, the containers shall be bonded to the equipment and grounded by a suitable grounding conductor.

6.4.5 Packaging and Storage.

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

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

6.5 In-Plant Conveying of Magnesium Powder.

6.5.1 Containers.

6.5.1.1* Transfer of powders in-plant shall be done in covered conductive containers, as described in Section 6.4.

6.5.1.2 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 Operation*.

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

6.5.2 Pneumatic Conveying.

6.5.2.1 If the conveying gas is air, the magnesium dust-to-air ratio throughout the conveying system shall be held safely below the minimum explosible concentration (MEC) of the magnesium dust at normal operating conditions. (See 6.3.2 and Annex C.)

6.5.2.2* Inert gas-conveying systems shall be permitted, if designed in accordance with Chapter 2 of NFPA 69, *Standard on Explosion Prevention Systems*.

6.5.2.3 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 inerting gas.

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

6.5.2.5* A minimum conveying velocity of 1068 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.

6.5.3 Ductwork for Conveying Systems.

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

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

6.5.3.1.2 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.

6.5.3.2* 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 pressure of 862 kPag (125 psig).

6.5.3.3 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.

6.5.3.4 Conveyor ducts shall be constructed of conductive material.

6.5.3.5 Nonconductive duct liners shall not be used.

6.5.3.6* Ducts shall be electrically bonded and grounded to minimize the accumulation of static electric charge. (See 6.4.2.2.)

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

6.5.4 Fan Construction and Arrangement.

6.5.4.1* 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.

6.5.4.2 Personnel shall not be permitted within 15 m (50 ft) of the fan while it is operating.

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

6.5.4.2.2 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 and with the knowledge and approval of operating management.

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

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

6.5.5 Dust Collectors.

6.5.5.1 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.4.3.2.5.2.)

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

CAUTION: This dust collector can contain explosible dust.

6.5.5.3 Ductwork shall comply with the provisions of 6.5.3.

6.5.5.4* 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.

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

6.5.5.5.1 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.

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

6.5.5.6 Repairs.

6.5.5.6.1 Where repairs on dry dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed. (*See Section 6.6.*)

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

6.6 Prevention of Fugitive Dust Accumulations.

6.6.1 General.

6.6.1.1 Fugitive dust shall not be allowed to accumulate.

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

6.6.1.1.2 Compressed-air blowdown shall not be permitted.

6.6.1.2* Vacuum-Cleaning Systems.

6.6.1.2.1 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.

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

6.6.1.2.3 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.

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

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

6.6.1.2.5.1 Assembled components shall be conductive and bonded where necessary.

6.6.1.2.5.2 Periodic tests for continuity shall be performed.

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

6.6.2 Cleaning Frequency.

6.6.2.1 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.

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

6.7 Storage of Magnesium Solids.

6.7.1* Storage of Pigs, Ingots, and Billets.

6.7.1.1 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 as per 6.7.1.2.4.

(B) The pile height shall not exceed 6.1 m (20 ft).

6.7.1.2 Yard (Outdoor) Storage.

6.7.1.2.1 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.

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

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

6.7.1.2.3.1 In no case, other than under the conditions of 6.7.1.2.3.2, shall the amount of magnesium stored exceed 45,400 kg (100,000 lb).

6.7.1.2.3.2 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 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.

6.7.1.2.4 Aisle width shall be at least one-half the height of the piles and shall be at least 3 m (10 ft).

6.7.1.2.5 Readily combustible material shall not be stored within a distance of 7.6 m (25 ft) from any pile of magnesium ingots.

6.7.1.2.6 An open space, equal to the height of the piles plus 3 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.

6.7.1.3* Indoor Storage.

6.7.1.3.1 Indoor storage shall be in buildings of noncombustible construction.

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

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

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

6.7.1.3.4.1 In no case, other than under the conditions of 6.7.1.3.4.2, shall the amount of magnesium stored exceed 23,000 kg (50,000 lb).

6.7.1.3.4.2 The quantities of magnesium stored shall be permitted to be increased up to a maximum of 226,800 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.

6.7.1.3.5 Aisle widths shall comply with 6.7.1.2.4.

6.7.1.3.6 Combustible material shall not be stored within a distance of 7.6 m (25 ft) from any pile of magnesium pigs, ingots, and billets.

6.7.2 Storage of Heavy Castings.

6.7.2.1 Except under the conditions of 6.7.2.2, buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

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

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

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

6.7.2.5 Storage Piles.

6.7.2.5.1 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 m³ (1270 ft³).

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

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

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

6.7.3 Storage of Light Castings.

6.7.3.1 Building Construction.

6.7.3.1.1 Except under the conditions of 6.7.3.1.2, light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage.

6.7.3.1.2 Storage of light castings shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system. (See 6.7.3.5.)

6.7.3.2 Piles of stored light magnesium castings, either in cartons or crates or without packing, shall be limited in size to 28 m³ (1000 ft³).

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

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

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

6.7.4 Storage in Racks or Bins.

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

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

6.7.4.3 All aisle spaces shall be kept clear.

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

6.7.4.5 Separators and metal sheets shall not be stacked on edge and leaned against racks, as they will prevent heat from a small fire from activating automatic sprinklers and will act as shields against sprinkler discharge.

6.7.5 Storage of Scrap Magnesium.

6.7.5.1 Subsection 6.7.5 shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

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

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

6.7.5.3.1 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.

6.7.5.3.2 Outside storage of magnesium fines shall be permitted if such storage is separated from buildings or personnel and great care is exercised so as to avoid the fines from becoming wet.

6.7.5.4* 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.

6.7.5.5* Storage of dry scrap in quantities greater than 1.4 m³ (50 ft³) [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.

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

6.7.5.7 Oily rags, packing materials, and similar combustibles shall be permitted in storage bins or areas that store solid magnesium scrap.

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

6.7.5.9 Fire-extinguishing agents compatible for the hazards present shall be readily available in magnesium scrap storage areas.

6.7.6 Storage of Magnesium Powder.

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

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

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

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

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

6.7.6.6* All areas used for the storage of magnesium powder shall be classified in accordance with Article 500 of NFPA 70, *National Electrical Code*.

6.7.6.7 Fire-extinguishing agents compatible for the hazards present shall be readily available in magnesium powder storage areas.

6.7.6.8* 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.

6.7.7 Storage of Other Magnesium Products.

6.7.7.1* Subsection 6.7.7 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.

6.7.7.2 Storage in quantities greater than 1.4 m³ (50 ft³) 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.

6.7.7.3 Magnesium products stored in quantities greater than 28 m³ (1000 ft³) shall be separated into piles, each not larger than 28 m³ (1000 ft³), with the minimum aisle width equal to the height of the piles but in no case less than 3.1 m (10 ft).

6.7.7.4* The storage area shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 28 m³ (1000 ft³) is contained in a building of combustible construction
- (2) Where magnesium products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 9 m (30 ft) of the magnesium

6.8 Fire Prevention and Fire Protection.

6.8.1 Fire Prevention. The provisions of Section 6.8 shall apply to all magnesium production processing, handling, and storage operations.

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

6.8.1.2* Hot Work.

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

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

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

6.8.1.4 Good housekeeping practices shall be maintained.

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

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

6.8.1.5 Ordinary Combustible Materials.

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

6.8.1.5.2 The requirement of 6.8.1.5.1 shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

6.8.1.6* Magnesium Chips or Powder.

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

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

6.8.1.7 Inspections.

6.8.1.7.1 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.

6.8.1.7.2 Records of the inspections specified in 6.8.1.7.1 shall be kept.

6.8.1.8* 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.

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

6.8.1.10 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.

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

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

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

6.8.1.14 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.

6.8.2* General Fire Protection.

6.8.2.1 A fire protection plan shall be provided for all areas where magnesium is present.

6.8.2.2* Sprinkler Protection.

6.8.2.2.1 Buildings or portions of buildings of noncombustible construction principally used for magnesium storage or handling shall not be permitted to be equipped with automatic sprinkler protection, except under the conditions of 6.8.2.2.2.

6.8.2.2.2 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted in areas where combustibles other than magnesium create a more severe hazard than the magnesium and where acceptable to an authority having jurisdiction that is knowledgeable of the hazards associated with magnesium.

6.8.2.2.3 If required by the authority having jurisdiction, automatic sprinkler protection, installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be provided for offices, repair shops, and warehouses not used for the storage of magnesium powder or chips.

6.8.2.3 As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the magnesium operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

6.8.2.4 Any fire-fighting organizations that respond to an emergency shall be trained in the hazards involved in fighting a magnesium fire.

6.8.3 Extinguishing Agents and Application Techniques.

6.8.3.1* Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing magnesium fires shall be permitted.

(A) A supply of extinguishing agent for manual application shall be kept within easy reach of personnel while they are working with magnesium.

(B) The quantity of extinguishing agent shall be sufficient to contain anticipated fires.

6.8.3.2* The use of pressurized extinguishing agents shall not be permitted on a magnesium powder fire or chip fire, unless applied carefully so as not to disturb or spread the magnesium powder.

(A) The application of pressurized extinguishing agents shall be performed only by trained personnel because of the dan-

ger of spreading the burning powder or chips or creating a dust cloud.

(B) Bulk dry extinguishing agents shall be provided in areas where chips and powders are produced or used.

(C) Bulk dry extinguishing agents shall be kept dry (that is, free of moisture).

6.8.3.3 Extinguishing agents intended for manual application shall be kept in identified containers.

(A) Container lids shall be secured in place to prevent agent contamination and to keep the agent free of moisture.

(B) Where large quantities of agent are expected to be needed, a clean, dry shovel shall be provided with the container.

(C) Where small amounts of agent are needed, a hand scoop shall be provided with each container.

6.8.3.4 Portable or wheeled extinguishers approved for use on magnesium fires shall be permitted and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

6.8.3.4.1* Only A:B:C or B:C dry-chemical portable fire extinguishers shall be provided in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*, for use on other classes of fires in areas where solid magnesium is present.

6.8.3.4.2 Water-based or CO₂ extinguishers shall not be provided in areas containing magnesium chips or powder, unless the conditions of 6.8.3.4.3 are met.

6.8.3.4.3 CO₂ extinguishers shall be permitted in areas containing magnesium for use on electrical fires.

6.8.3.4.4 The CO₂ extinguishers specified in 6.8.3.4.3 shall be clearly marked "Not for use on magnesium fires."

6.8.3.5* Dry sodium chloride, or other dry chemicals or compounds suitable for extinguishment or containment of magnesium fires, shall be permitted to be substituted for Class D fire extinguishers.

(A) The alternative agents specified in 6.8.3.5 shall be stored in a manner that ensures the agent's effectiveness.

(B) Shovels or scoops shall be kept readily available adjacent to the containers.

(C) All extinguishing agent storage areas shall be clearly identified.

6.8.3.6 Magnesium fines shall be segregated by storage in noncombustible drums.

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

(A) When feed is stopped, the equipment shall be kept in operation, unless the conditions of 6.8.3.7(B) are met.

(B) Where continued operation of equipment would cause the spread of fire, the equipment shall be stopped.

Chapter 7 Tantalum

7.1 Construction of Production Plants.

7.1.1 Plant Construction.

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

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

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

7.1.1.4 Floors.

7.1.1.4.1 Floors in facilities shall be made of noncombustible materials.

7.1.1.4.2 A hazard 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.)

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

7.1.1.6 Roof decks shall be watertight.

7.1.1.7 Drying Rooms.

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

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

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

7.1.1.9 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 Fire Walls and Fire Barrier Walls*.

7.1.1.10 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 Fire Windows*.

7.1.1.11 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.

7.1.1.12 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.

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

7.1.1.14* Water pipes or pipes that can contain water for uses other than process or production support (for example, sprinkler piping, domestic water, roof drains, and waste pipes) shall be permitted where a process hazard analysis is performed by a person knowledgeable in the hazards of tantalum who is acceptable to the authority having jurisdiction.

7.1.2* Grounding of Equipment.

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

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

7.1.3 Electrical Power.

7.1.3.1 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*.

7.1.3.2* 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*.

7.1.3.3 All hazardous (classified) areas identified in accordance with 7.1.3.2 shall be documented, and such documentation shall be maintained on file for the life of the facility.

7.1.4 Explosion Mitigation/Venting.

7.1.4.1 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.

7.1.4.2* Deflagration Venting.

7.1.4.2.1* 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 NFPA 68, *Guide for Venting of Deflagrations*.

7.1.4.2.2* 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.

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

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

7.1.5 Management of Change.

7.1.5.1 The requirements of 7.1.5.2, 7.1.5.3, 7.1.5.4, and 7.1.5.5 shall apply to existing facilities and processes.

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

7.1.5.3 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

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

7.1.5.5 Design documentation shall be updated to incorporate the change.

7.2 Melting Operations for Primary Producers.

7.2.1* Explosion Prevention.

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

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

7.2.1.3* 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.

7.2.1.4 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.

7.2.1.5* Upper Chamber of the Furnace.

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

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

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

7.2.1.5.4 Large low-pressure ports shall not be used.

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

7.2.1.7 Pressure-Sensing Device.

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

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

7.2.1.8* 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

7.2.1.9 Furnaces shall comply with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, or NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

7.2.1.10 Water Supply.

7.2.1.10.1 The water supply to crucibles shall be monitored continuously by a system that automatically interrupts power to the melting heat source upon a drop in water pressure or waterflow.

7.2.1.10.2 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.

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

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

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

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

7.2.2 Casting.

7.2.2.1 Water Supply.

7.2.2.1.1* 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.

7.2.2.1.2 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.

7.2.2.2 Molds.

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

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

7.2.2.3 Since mold breaks are inevitable, the casting chamber shall be cooled or shall be large enough to serve as a heat sink, or both, in order to provide the protection necessary in the event of a spill.

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

7.2.2.5 Residue.

7.2.2.5.1* 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.

7.2.2.5.2 The containers specified in 7.2.2.5.1 shall be stored so that any hydrogen gas generated vents freely.

7.2.3 Personnel Safety Precautions.

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

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

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

7.3* Milling, Machining, and Fabrication Operations.

7.3.1 Machining Operations.

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

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

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

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

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

7.3.1.4 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.

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

7.3.1.6* 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).

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

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

7.3.1.8.1 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).

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

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

7.3.2* 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 7.10.1.1 for additional requirements.)

7.4 Tantalum Powder Manufacturing for Primary Producers.

7.4.1 General.

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

7.4.1.2* 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.

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

7.4.1.4 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 Operation*.

7.4.1.5 To minimize the risk of fire or explosion hazard in the handling of tantalum powders, the equipment and processes

shall be designed by people experienced and knowledgeable in the hazards of tantalum powders.

7.4.2* Drying of Tantalum Powder.

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

7.4.2.2 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).

7.4.2.3 When drying tantalum powders under controlled atmospheric conditions (for example, 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.

7.4.2.4 Dryers.

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

7.4.2.4.2 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.

7.4.2.4.3 Dryers shall be constructed of noncombustible materials.

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

7.4.2.4.5 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.

7.4.2.4.6 Explosion protection shall be provided as specified in 7.4.5.

7.4.2.4.7 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.

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

7.4.2.4.9 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

7.4.2.4.10* Excess temperature-limit controls required in 7.4.2.4.9 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) Maintain purge flow of inert gas
- (6) Maintains coolant flow, if so equipped

7.4.2.4.11 An emergency stop shall be provided that will enable manual initiation of the automatic shutdown required by 7.4.2.4.10.

7.4.2.4.12 All automatic shutdowns required by 7.4.2.4.10 shall require manual reset before the dryer can be returned to operation.

7.4.3 Tantalum Powder Handling.

7.4.3.1 Where tantalum powder is present, good housekeeping practices shall be maintained.

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

7.4.3.3 Scoops, shovels, and scrapers used in the handling of dry tantalum powder shall be electrically conductive and shall be bonded and grounded.

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

7.4.3.5* Sintering furnaces that handle tantalum parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, or NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

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

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

7.4.4 Electrical Installations.

7.4.4.1 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.

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

7.4.4.3* Where dry tantalum powders are charged to or discharged from equipment, the containers shall be bonded and grounded.

7.4.4.4 When transferring dry tantalum powder between containers, the containers shall be bonded and grounded.

7.4.5 Explosion Prevention/Protection.

7.4.5.1* 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.

7.4.5.2 Where explosion protection is required per 7.4.5.1, 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*

7.4.5.3 If the method specified in 7.4.5.2(5) is used, test data for specific dust and dilution combinations shall be provided and shall be acceptable to the authority having jurisdiction.

7.4.5.4 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.

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

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

7.4.8 Personnel Safety Precautions.

7.4.8.1* Personnel handling tantalum powder shall wear static-dissipative footwear and flame-resistant clothing that is designed to minimize the accumulation of tantalum powder.

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

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

7.4.8.4* Access to tantalum powder-handling areas by unauthorized personnel shall not be permitted.

7.4.9 Housekeeping Practices.

7.4.9.1 Good housekeeping practices shall be followed so that accumulations of tantalum powder are minimized.

7.4.9.2 Special attention shall be paid to tantalum powder accumulations in crevices and joints between walls and floors. (See 7.10.1.4.)

7.5 Tantalum Powder End Users.

7.5.1 General.

7.5.1.1* Equipment shall be constructed to mitigate the potential for ignition of tantalum powder.

7.5.1.2* 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.

7.5.1.3 A hazard analysis shall be performed for areas where tantalum powder is present to determine risk factors and appropriate controls.

7.5.1.4* Where the hazard 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.

7.5.1.5* 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.

7.5.1.6* Spark-resistant tools shall be used.

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

7.5.2 Tantalum Powder Storage.

7.5.2.1 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.

7.5.2.2 Stacked Storage.

7.5.2.2.1 When storing tantalum powder in sealed containers, stacked storage shall be arranged to ensure stability.

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

7.5.3 Dry Tantalum Powder Handling.

7.5.3.1* Precautions shall be taken to prevent spills or dispersions that produce tantalum dust clouds.

7.5.3.2 Sintering furnaces that handle compacted tantalum powder shall be installed and operated in accordance with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, or NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

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

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

7.5.4 Wet Tantalum Powder Handling.

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

7.5.4.2 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).

7.5.4.3 When drying tantalum powders under controlled atmospheric conditions (for example, 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.

7.6 Heat Treatment and Passivation.

7.6.1 General.

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

7.6.1.2 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*.

7.6.1.3 Furnaces shall comply with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, or

NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

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

7.6.3* Personnel Safety Precautions.

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

7.6.3.2 Access to tantalum-handling areas by unauthorized personnel shall not be permitted.

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

7.6.4 Tantalum Powder Heat Treatment and Sintering.

7.6.4.1 After tantalum powder furnacing, the tantalum powder shall be passivated prior to exposure to air atmosphere.

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

7.6.5* Heat Treatment and Sintering of Tantalum Compacts.

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

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

7.6.6 Safety Precautions.

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

7.6.6.2 The alternate cooling system specified in 7.6.6.1 shall be activated automatically upon failure of the main cooling source and shall be interlocked to prevent operation of the furnace.

7.7 Dust Collection for Tantalum Operations.

7.7.1 Dust-Producing Operations.

7.7.1.1 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.

7.7.1.2* 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.

7.7.1.3 Dust-collection systems handling tantalum shall be provided with explosion protection as required under 7.4.5.

7.7.2 Dust-Collection Ducts and Ductwork.

7.7.2.1 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*.

7.7.2.2 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 can fall out before delivery to the collector (for example, in the event of power failure).

7.7.2.3 Ducts shall be designed to handle a volumetric flow rate that maintains dust loading safely below the minimum explosible concentration (MEC).

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

7.7.2.5 Duct Construction.

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

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

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

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

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

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

7.7.3 Wet-Type Dust Collectors.

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

7.7.3.2* 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.

7.7.3.3* 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.

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

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

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

7.7.3.7 Collector Sump Venting.

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

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

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

7.7.3.8 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 a visual and audible alarm at the equipment it serves and at an area that is occupied at all times that the equipment is in operation.

7.7.3.9 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.

7.7.4* Dry-Type Dust Collectors.

7.7.4.1 Electrostatic and media collectors shall not be used.

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

7.7.4.3 Design.

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

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

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

7.7.4.5 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.

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

7.7.4.7 Repairs.

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

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

7.7.4.8 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.

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

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

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

7.8 In-Plant Conveying of Tantalum Powder.

7.8.1 Enclosed Mechanical Conveyors.

7.8.1.1 Housings for enclosed conveyors (for example, screw and drag conveyors) shall be of metal construction and shall be designed to prevent escape of tantalum powders.

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

7.8.1.3* 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 7.4.5.

7.8.1.4 Power Shutoff.

7.8.1.4.1 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.

7.8.1.4.2 Feed to the conveyor shall be stopped or diverted.

7.8.2 Pneumatic Conveying.

7.8.2.1 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*.

7.8.2.2 Power Shutoff.

7.8.2.2.1 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.

7.8.2.2.2 Feed to the conveyor shall be stopped or diverted.

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

7.8.3 Ductwork for Conveying Systems.

7.8.3.1 Nonconductive duct or duct liners shall not be used.

7.8.3.2 Ducts shall be electrically bonded and grounded.

7.8.3.3* Deflagration venting (for example, rupture diaphragms) shall be provided on ductwork.

7.8.3.3.1 Deflagration vents shall relieve to a location outside of the building.

7.8.3.3.2* The design of deflagration venting shall be in accordance with NFPA 68, *Guide for Venting of Deflagrations*.

7.8.3.4 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 pressure of 862 kPag (125 psig).

7.8.3.5 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.

7.8.4 Fan Construction and Arrangement.

7.8.4.1 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*.

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

7.8.4.3 Fan motors shall be located outside of the duct airstream.

7.9 General Storage of Tantalum.

7.9.1 Storage with Incompatible Materials. Tantalum shall not be stored in an area with incompatible materials.

7.9.2 Scrap Storage.

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

7.9.2.2 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.

7.9.3 Powder Storage.

7.9.3.1* Tantalum powder shall be stored in covered containers.

7.9.3.2 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.

7.9.3.3 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 m (10 ft).

7.9.3.4 Stacked storage shall be arranged to ensure stability.

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

7.9.4 Other Production Materials.

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

7.9.4.2 Sodium Operations. All sodium storage, handling, and processing operations shall be in accordance with Chapter 10.

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

7.10 Fire Prevention and Fire Protection.

7.10.1 Fire Prevention. The provisions of Section 7.10 shall apply to all tantalum powder production processes, handling, and storage operations.

7.10.1.1 Hot Work.

7.10.1.1.1* 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.

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

7.10.1.1.3 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.

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

7.10.1.3 Ignition Prevention.

7.10.1.3.1 All machinery shall be installed and maintained in such a manner that the possibility of frictional sparks is minimized.

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

7.10.1.3.3 Grounded and bonded bearings shall be used and properly sealed against tantalum dust.

7.10.1.3.4 In areas containing tantalum dust, process and comfort heating shall be provided by indirect means.

7.10.1.3.5 Open-flame nonprocess equipment shall be located outdoors or in a separate, tantalum dust-free room or building.

7.10.1.3.6 Air for combustion shall be taken from a clean, outside source.

7.10.1.3.7 Comfort air shall not be permitted to flow from areas classified under Article 500 of the NFPA 70, *National Electrical Code*, to nonclassified areas.

7.10.1.4 Housekeeping. Fugitive tantalum dust shall not be allowed to accumulate. (See A.4.4.2.1.)

7.10.1.4.1 Inspections.

7.10.1.4.1.1 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.

7.10.1.4.1.2 Records of the inspections specified in 7.10.1.4.1.1 shall be kept.

7.10.1.4.2* 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.

7.10.1.4.3* Bulk accumulations of fine tantalum shall be removed by natural fiber push brooms and nonsparking scoops or shovels before vacuum-cleaning equipment is used.

7.10.1.4.3.1 Cleanup of the bulk of spilled powder shall be accomplished using conductive, nonsparking scoops and natural fiber brooms or brushes that have natural fiber bristles.

7.10.1.4.3.2 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.

7.10.1.4.4 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.

7.10.1.4.5* 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 7.1.3.2.)

(C) Blowing down of any surfaces by compressed air shall be prohibited.

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

7.10.1.6 Where ordinary combustible materials are necessary for the process and are stored in designated areas, 7.10.1.5 shall not apply.

7.10.1.7 Ordinary combustible materials shall not be discarded in containers used for the collection of chips or powder.

7.10.1.8 Floor sweepings from tantalum operations shall be permitted to contain small amounts of ordinary combustible materials and shall be stored in separate containers.

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

7.10.1.10 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.

7.10.2 General Fire Protection.

7.10.2.1 A fire protection plan shall be developed and implemented.

7.10.2.2* Buildings or portions of buildings of noncombustible construction principally used for tantalum powder storage or handling shall not be permitted to be equipped with automatic sprinkler protection, except under the conditions of 7.10.2.3.

7.10.2.3 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted in areas where combustibles other than tantalum create a more severe hazard than the tantalum powder and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with tantalum powder.

7.10.2.4 If required by the authority having jurisdiction, automatic sprinkler protection, installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be provided for offices, repair shops, and warehouses not used for the storage of tantalum powder, or chips.

7.10.2.5 As an alternative, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the tantalum operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

7.10.2.6 Where automatic sprinklers are installed, dust accumulation on overhead surfaces shall be minimized to prevent sprinkler heads beyond the sprinkler system design area from opening in the event of a fire.

7.10.3* Extinguishing Agents and Application Techniques.

7.10.3.1* Only listed, Class D extinguishing agents and those agents tested and shown to be effective for controlling tantalum fires shall be provided.

7.10.3.2 A supply of extinguishing agent for manual application shall be kept within easy reach of personnel while working with tantalum powder.

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

7.10.3.4 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*.

7.10.3.5 The following agents shall not be used as extinguishing agents on a tantalum fire because of adverse reaction or ineffectiveness:

- (1) Water
- (2) Foams
- (3) Halon
- (4) Carbon dioxide
- (5) Nitrogen

7.10.3.6 An A:B:C dry chemical and a B:C dry-chemical extinguisher shall not be used as a tantalum fire-extinguishing agent but shall be permitted to be used on other classes of fires in the area where tantalum is present.

7.10.3.7 Fire-extinguishing agent expellant gases shall be compatible with tantalum.

7.10.4 Tantalum Fire-Fighting Procedures.

7.10.4.1 Tantalum fires beyond the incipient stage shall be fought by professional fire fighters, specially trained fire brigade personnel, or both.

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

7.10.4.3 Tantalum fire residues shall be protected to prevent adverse reactions and to prevent the formation of reactive or unstable compounds.

7.10.4.4 Tantalum fire residues shall be disposed of in accordance with federal, state, and local regulations.

7.10.5 Fighting Tantalum Fires.

7.10.5.1* Trained employees shall be permitted to fight incipient-stage fires, provided the fire can be controlled with portable extinguishers or other dry extinguishing agent (*see 7.10.3.1*).

7.10.5.2 Trained employees shall not need to don any protective clothing other than their work clothes to fight the fire.

7.10.6 Inspection and Maintenance.

7.10.6.1 Operating Procedures and Emergency Plans.

7.10.6.1.1 Operating and maintenance procedures and emergency plans shall be developed.

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

7.10.6.2 Initial and refresher training shall be provided that ensures that all employees are knowledgeable about the following:

- (1) Hazards of their workplace
- (2) General orientation including plant safety rules
- (3) Process description
- (4) Equipment operation, start-up and shutdown, and response to upset conditions
- (5) Necessity for functioning of related fire and explosion protection systems
- (6) Equipment maintenance requirements and practices
- (7) Emergency response plans
- (8) Hazards posed by causing dust clouds and the danger of applying water, halogen agents, foam, nitrogen, or carbon dioxide onto an incipient fire

7.10.6.3 An inspection, testing, and maintenance program shall be implemented that ensures that the fire and explosion protection systems and related process controls and equipment perform as designed, and that a change in process equipment does not increase the hazard.

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

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

Chapter 8 Titanium

8.1 Sponge Production.

8.1.1 Plant Construction.

8.1.1.1 Buildings housing reduction furnaces, boring and crushing facilities, and titanium refining operations shall be constructed of noncombustible materials.

8.1.1.2* Consideration shall be given to the provision of explosion venting in accordance with current accepted practices.

8.1.1.3 Building exits shall comply with NFPA 101, *Life Safety Code*.

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

8.1.1.5 Titanium winning, refining, and casting operations shall be protected from rain and from other possibilities of inadvertent contact with water.

8.1.1.6 Permanent water lines in the winning, refining, and casting operations area shall be of all metal construction.

8.1.1.7 Hose used for cleaning and washdown purposes shall be pressurized only while in active use for cleaning and washdown operations.

8.1.2 Processing Equipment.

8.1.2.1 Reactor vessels shall be air-cooled.

8.1.2.2 Sealed titanium-reduction vessels shall be permitted to be water-cooled and shall be designed to prevent water from entering the reaction vessel.

8.1.2.3 Furnaces shall be kept dry and free of iron scale and metal spillage.

8.1.2.4* 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.

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

8.1.3 Storage of Raw Materials.

8.1.3.1 Magnesium ingots for use in the Kroll process shall be stored in accordance with Chapter 6.

8.1.3.2* Chlorine shall be handled and stored in accordance with accepted industry practice.

8.1.3.3* 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.

8.1.4 Dust Collection.

8.1.4.1 Dust resulting from the crushing of titanium sponge shall be managed safely to minimize the risk of fires and explosions.

8.1.4.2 Media collectors shall not be used for the collection of titanium sponge fines.

8.1.4.3* Dust collectors for Kroll-distilled material shall be located outside buildings and shall be provided with explosion vents.

8.1.4.4* 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*.

8.1.5* **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.

8.1.6 Sponge Storage.

8.1.6.1 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.

8.1.6.2 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 8.7, and shall be plainly marked with "No Smoking" signs.

8.1.6.3 Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of not more than four pallet loads.

8.1.6.4 Stacked storage shall be positioned in such a manner as to ensure stability.

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

8.2 Titanium Melting.

8.2.1* Explosion Prevention.

8.2.1.1 Water Supply.

8.2.1.1.1 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.

8.2.1.1.2 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.

8.2.1.2 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.

8.2.1.3* 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 kPag (20 psig) maximum.

(C) Large low-pressure ports shall not be used.

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

8.2.1.5 The use of a magnetic field to deflect the electric arc away from the crucible wall shall be considered.

8.2.1.6 Pressure-Sensing Device.

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

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

8.2.1.7 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

8.2.2* Casting.

8.2.2.1* Water Supply.

8.2.2.1.1 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.

8.2.2.1.2 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.

8.2.2.2 Molds.

8.2.2.2.1 Molds for titanium casting shall be made of material that is compatible with molten titanium.

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

8.2.2.3 The casting chamber shall be cooled or shall be sufficiently massive, or both, to accommodate a spill, since mold breaks are inevitable.

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

8.2.2.5* Residue from casting furnaces shall be placed in steel boxes and moved outside the building.

8.3 Mill Operations.

8.3.1* Scope. Mill operations shall cover the forging and finishing of titanium products in a primary production facility.

8.3.2 Fire Prevention.

8.3.2.1 Tanks in which flammable or combustible solvents are used for degreasing shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

8.3.2.2* Sawing, grinding, polishing, buffing, and cutting equipment shall be grounded.

8.3.2.3 All titanium chips shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

8.3.2.4 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) if oil leaks are anticipated.

8.3.2.5 Flammable and combustible liquids coatings applied to ingots or billets shall meet the requirements of NFPA 34, *Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids*.

8.3.2.6 Oily crushed lathe turnings, raw turnings, and swarf shall be collected in closed-top metal containers and removed daily, as a minimum, to a safe storage or disposal area.

8.3.2.7 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.

8.4 Machining, Fabrication, and Finishing of Parts.

8.4.1 Scope.

8.4.1.1 Section 8.4 shall apply to operations where titanium is subjected to processing or finishing operations.

8.4.1.2 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.

8.4.2 Machining Operations.

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

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

8.4.3 Welding.

8.4.3.1 All welding of titanium shall be carried out under an inert atmosphere, such as helium, argon, or under vacuum.

8.4.3.2 Fabrication processes using 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.

8.4.4 Titanium Dust Collection.

8.4.4.1 Hoods or Enclosures.

8.4.4.1.1 Titanium dust shall be collected by means of hoods or enclosures at each dust-producing operation.

8.4.4.1.2* 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.

8.4.4.2 Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded.

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

8.4.4.2.2 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*.

8.4.4.3 Titanium dust-producing equipment shall be connected to dust-collecting equipment.

8.4.4.3.1 Multiple pieces of titanium dust-producing equipment shall be permitted to be connected to a single titanium dust-collecting unit.

8.4.4.3.2 An evaluation shall be made to determine if multiple pieces of dust-producing equipment can be served safely by a single dust-collecting unit.

8.4.4.4* 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.

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

Current Use: Titanium — Fire or Explosion Can Result
with Other Metals

8.4.4.6 Power Supply.

8.4.4.6.1 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.

8.4.4.6.2 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.

8.4.4.7 Sludge from dust collectors and vacuum-cleaning system precipitators shall be removed daily as a minimum.

8.4.4.7.1 Covered, vented steel containers shall be used to transport collected sludge to a safe storage area or for disposal.

8.4.4.7.2 Sludge shall be disposed of in accordance with federal, state, and local regulations.

8.4.5 Dust-Producing Operations.

8.4.5.1 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.

8.4.5.1.1 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.

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

8.4.5.2* 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.

8.4.5.3 Machining Coolant.

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

8.4.5.3.2 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.

8.4.6 Dust-Collection Ducts and Ductwork.

8.4.6.1 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*.

8.4.6.2 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 can fall out before delivery to the collector (for example, in the event of power failure).

8.4.6.3 Ducts shall be designed to handle a volumetric flow rate that maintains dust loads safely below the minimum explosion concentration (MEC).

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

8.4.6.5 Duct Construction.

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

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

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

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

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

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

8.4.7 Wet-Type Dust Collectors.

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

8.4.7.1.1 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.

8.4.7.1.2 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 accumulations of particulate matter in the work area.

8.4.7.2* 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.

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

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

8.4.7.5 The dust collector shall be arranged so that the dust-laden airstream is thoroughly scrubbed by the liquid to achieve the desired efficiency.

8.4.7.6 Collector Sump Venting.

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

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

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

8.4.7.7 Power Supply.

8.4.7.7.1 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.

8.4.7.7.2 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.

8.4.8 Dry-Type Dust Collectors.

8.4.8.1 Electrostatic and media collectors shall not be used.

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

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

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

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

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

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

8.4.8.6.2 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.

8.4.8.6.3 Dry collectors shall be emptied before or when 80 percent of the storage capacity of the collector is attained.

8.4.8.6.4 The maximum volume of titanium fines collected before emptying shall not exceed 19 L (5 gal).

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

8.4.8.7.1 The cyclone dust collector shall be solid-welded with smooth internal seams.

8.4.8.7.2 The equipment shall be provided with a sparkproof air lock on the hopper discharge and connected to a covered material receiver.

8.4.8.7.3 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.

8.4.8.7.4 Motors and controls of any type associated with the process airstream shall be located outside of the process airstream.

8.4.8.7.5 All equipment shall be bonded and grounded.

8.4.8.8 Repairs.

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

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

8.4.8.9 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.

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

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

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

8.5 Scrap Storage.

8.5.1* Storage.

8.5.1.1 Open storage of sheet, plate, forgings, or massive pieces of scrap presents no fire risk and shall be permitted.

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

8.5.1.3 Storage of materials in closed noncombustible containers shall not be subject to the requirements of 8.5.1.2.

8.6 Titanium Powder Production and Use.

8.6.1* Drying and Storage of Titanium Powder.

8.6.1.1 Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

8.6.1.2* 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.

8.6.1.3 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.

8.6.2 Titanium Powder Handling.

8.6.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

8.6.2.2 Powder or dust shall not be allowed to accumulate in the furnace or near the heating elements.

8.6.2.2.1 Hot zones of furnaces that handle titanium parts shall be provided with inert atmospheres or vacuum.

8.6.2.2.2 The furnaces shall be designed in accordance with NFPA 86, *Standard for Ovens and Furnaces*.

8.6.2.3* To minimize the risk of fire or explosion hazards in the handling of dry titanium powders, the equipment and processes shall be designed by people knowledgeable in the hazards of titanium powders.

8.6.2.4 Electrical Installations. All titanium 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 present, which shall be installed in accordance with the requirements of NFPA 70, *National Electrical Code*.

8.6.3 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.

8.7 Fire Prevention and Fire Protection.

8.7.1 Fire Prevention. The provisions of Section 8.7 shall apply to all titanium production, processing, handling, and storage operations.

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

8.7.1.2 Sponge Collection.

8.7.1.2.1 Sponge discharged from dryers shall be collected in containers that have a capacity no larger than 1814 kg (4000 lb).

8.7.1.2.2 The collection area shall be well-ventilated and free from other combustible material.

8.7.1.3* Hot Work.

8.7.1.3.1 Hot-work permits shall be required in designated areas that contain exposed titanium fines, powder, dust, or sponge where hot work is conducted.

8.7.1.3.2 All hot-work areas that require a permit shall be thoroughly cleaned of titanium fines, dust, or sponge before hot work is performed.

8.7.1.4* Molten Titanium.

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

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

8.7.1.5 Housekeeping.

8.7.1.5.1 Systematic cleaning of the entire building containing dust-producing equipment, including roof members, pipes, conduits, and so on, shall be conducted as conditions warrant.

8.7.1.5.2 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.

8.7.1.5.3 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.

8.7.1.5.4 To prevent potential explosions caused by inadvertently using high-pressure compressed air in place of low-pressure inert gas, fittings used on compressed-air and inert gas-line outlets shall not be interchangeable.

8.7.1.6 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in titanium processing areas unless necessary for the process and, then, only in designated areas.

8.7.1.7 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.

8.7.1.8 Inspections.

8.7.1.8.1 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.

8.7.1.8.2 Records shall be kept of the inspections specified in 8.7.1.8.1.

8.7.1.9 Combustible materials shall not be discarded in containers used for the collection of dust, swarf, or turnings.

8.7.1.10 Oil spills shall be cleaned up immediately.

8.7.1.11 Smoking.

8.7.1.11.1 Smoking shall be permitted only in designated areas.

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

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

8.7.1.13 Only nonsparking tools and utensils shall be used in handling titanium powder.

8.7.1.14* All metal objects or equipment used to process titanium shall be electrically bonded and grounded to prevent accumulations of static electricity.

8.7.1.15 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.

8.7.1.16 Areas used for torch-cutting of titanium shall be kept free of combustible materials.

8.7.2* Fire Protection.**8.7.2.1* Sprinkler Protection.**

8.7.2.1.1 Except under the conditions of 8.7.2.1.2, buildings or portions of buildings of noncombustible construction used principally for the storage of titanium chips, powders, fines, or titanium with a thickness less than 0.038 cm (0.015 in.), or for titanium handling, shall not be permitted to be equipped with automatic sprinkler protection.

8.7.2.1.2 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted in areas where combustibles other than titanium create a more severe hazard than the titanium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with titanium.

8.7.2.2 If required by the authority having jurisdiction, automatic sprinkler protection installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be provided for offices, repair shops, and warehouses not used for the storage of titanium sponge, fines, or chips.

8.7.2.3* Portable Fire Extinguishers.

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

8.7.2.3.1.1 Water-based or CO₂ extinguishers shall not be provided in areas containing titanium sponge, fines, or chips.

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

8.7.2.3.1.3 Where Class A, Class B, or Class C fire hazards are in the combustible titanium powder area, extinguishers suitable for use on such fires shall be permitted, provided they are marked "not for use on titanium powder fires."

8.7.2.3.2 If portable extinguishers are to be used on metal fires, they shall be approved for use on Class D fires.

8.7.2.4* Dry sodium chloride, or other dry chemicals or compounds suitable for extinguishment or containment of titanium

fires, shall be permitted to be substituted for Class D fire extinguishers.

8.7.2.4.1 The alternative agents specified in 8.7.2.4 shall be stored in a manner that ensures the agents' effectiveness.

8.7.2.4.2 Shovels or scoops shall be kept readily available adjacent to the containers.

8.7.2.4.3 All extinguishing agent storage areas shall be identified clearly.

8.7.2.5 Titanium Fines.

8.7.2.5.1 Titanium fines shall be segregated by storage in noncombustible drums or tote bins.

8.7.2.5.2 When drums or tote bins of burning materials can safely be moved, they shall be moved away from processing equipment and out of buildings as rapidly as possible.

8.7.2.6 Processing Equipment.

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

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

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

8.7.2.8 Fire-Fighting Organization.

8.7.2.8.1 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.

8.7.2.8.2 Training.

8.7.2.8.2.1 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.

8.7.2.8.2.2 Training shall include all possible contingencies.

8.7.2.8.3* If professional or volunteer fire fighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by a unified incident command that includes knowledgeable plant personnel.

Chapter 9 Zirconium

9.1 Sponge Production.

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

9.1.2 Plant Construction.

9.1.2.1 Buildings housing reduction furnaces, boring and crushing facilities, and magnesium refining operations shall be constructed of noncombustible materials.

9.1.2.2* Consideration shall be given to the provision of deflagration venting in accordance with current accepted practices.

9.1.2.3 Building exits shall comply with NFPA 101, *Life Safety Code*.

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

9.1.2.5 Fittings used on compressed-air and inert gas-line outlets shall not be interchangeable to prevent potential explosions caused by inadvertently using compressed air in place of low-pressure inert gas.

9.1.3 Processing Equipment.

9.1.3.1 Chlorinators and reduction vessels shall be designed and maintained to prevent water from entering the reaction chamber.

9.1.3.2 Furnaces shall be kept dry and free of iron scale and other foreign material.

9.1.3.3 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*.

9.1.3.4* Furnaces shall comply with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*, and NFPA 86D, *Standard for Industrial Furnaces Using Vacuum as an Atmosphere*.

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

9.1.3.6 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.

9.1.4 Storage of Raw Materials.

9.1.4.1* Chlorine shall be handled and stored in accordance with accepted industry practice.

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

9.1.4.3* Bulk Containers.

9.1.4.3.1 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.

9.1.4.3.2 Containers shall be identified plainly and tightly sealed until used.

9.1.5 Dust Collection.

9.1.5.1 Dust resulting from the crushing of zirconium sponge shall be managed safely to minimize the risk of fires and explosions.

9.1.5.2 Media collectors shall not be used for the collection of zirconium sponge fines.

9.1.5.3 Collected Material.

9.1.5.3.1 Nonmedia-based dry collectors shall be emptied before, or when, 80 percent of the storage capacity is attained.

9.1.5.3.2 The maximum volume of zirconium fines collected before emptying shall not exceed 19 L (5 gal).

9.1.5.4* Dust collectors for Kroll-distilled material shall be located outside buildings and shall be provided with deflagration vents.

9.1.5.5* 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*.

9.1.6* 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.

9.1.7 Sponge Storage.

9.1.7.1 Dry zirconium sponge shall be stored in closed metal containers with a maximum capacity that is capable of being moved by available equipment.

9.1.7.2* Wet zirconium sponge shall be stored in nonsealing, covered metal containers with a maximum capacity that is capable of being moved by available equipment.

9.1.7.3 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.

9.1.7.4 Where drums are used, storage shall be limited to one-drum tiers per pallet with a height of not more than four pallet loads.

9.1.7.5 Stacked storage shall be arranged to ensure stability.

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

9.2* Zirconium Melting.

9.2.1 Explosion Prevention.

9.2.1.1 Water Supply.

9.2.1.1.1 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.

9.2.1.1.2 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.

9.2.1.2 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.

9.2.1.3* 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 of 138 kPag (20 psig).

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

9.2.1.5 Pressure-Sensing Device.

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

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

9.2.1.6 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

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 upon 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 zirconium casting shall be made of material that is compatible with molten zirconium.

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

9.2.2.3 Since mold breaks are inevitable, the casting chamber shall be cooled or shall be large enough to serve as a heat sink, or both, in order 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 from casting furnaces shall be placed in steel boxes and moved outside the building.

9.3* Mill Operations.

9.3.1 Fire Prevention.

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

9.3.1.2* All electrically driven equipment used for sawing, cutting, or grinding operations shall be grounded in accordance with NFPA 70, *National Electrical Code*.

9.3.1.3 Zirconium chips shall be collected in covered metal containers and removed daily, as a minimum, to a safe storage or disposal area.

9.3.1.4 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).

9.3.2 Coolants.

9.3.2.1 Nonflammable coolants shall be used for wet grinding, cutting, and sawing operations.

9.3.2.2 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.

9.3.2.3 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*.

9.3.2.4 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.

9.3.2.5 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.

9.4 Machining and Fabrication.

9.4.1 Machining Operations.

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

9.4.1.2 Nonflammable coolants or lubricants shall be used to minimize heat generated by the cutting operation.

9.4.2 Welding.

9.4.2.1 All welding of zirconium shall be carried out under a helium or argon atmosphere or under vacuum.

9.4.2.2* 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 chips or powder have been removed and exposed equipment has been cleaned thoroughly.

9.4.3 Zirconium Dust Collection.

9.4.3.1 Hoods or Enclosures.

9.4.3.1.1 Zirconium dust shall be collected by means of hoods or enclosures at each dust-producing operation.

9.4.3.1.2* 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.

9.4.3.2 Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded.

9.4.3.2.1 Ducts and tubes shall be as short as practicable, with no unnecessary bends.

9.4.3.2.2 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*.

9.4.3.3 Zirconium dust-producing equipment shall be connected to dust-collecting equipment.

9.4.3.3.1 Multiple pieces of zirconium dust-producing equipment shall be permitted to be connected to a single zirconium dust-collecting unit.

9.4.3.3.2 An evaluation shall be made to determine if multiple pieces of dust-producing equipment can be safely served by a single dust-collecting unit.

9.4.3.4* 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.

9.4.3.5 Power Supply.

9.4.3.5.1 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.

9.4.3.5.2 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.

9.4.3.6 Housekeeping.

9.4.3.6.1 Systematic cleaning of the entire building containing dust-producing equipment, including roof members, pipes, conduits, and other components, shall be conducted as conditions warrant.

9.4.3.6.2 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.

9.4.3.6.3 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.

9.4.3.7* Sludge from dust collectors and vacuum-cleaning system precipitators shall be removed daily, as a minimum, and shall be kept thoroughly wet.

9.4.3.7.1 Nonsealing, covered metal containers shall be used to transport collected sludge to a safe storage area or for disposal.

9.4.3.7.2 Sludge shall be disposed of in accordance with federal, state, and local regulations.

9.5* Scrap Storage.

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

9.5.2 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.

9.6* Zirconium Powder Production and Use.

9.6.1 Drying and Storage of Zirconium Powder.

9.6.1.1* Wetted powder shall be dried at a temperature not exceeding 110°C (230°F).

9.6.1.2* 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.

9.6.1.3 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.

9.6.2 Zirconium Powder Handling.

9.6.2.1 Special care shall be taken to prevent spills or dispersions that produce dust clouds.

9.6.2.2* Sintering furnaces that handle zirconium parts that are fabricated from powder shall be installed and operated in accordance with NFPA 86C, *Standard for Industrial Furnaces Using a Special Processing Atmosphere*.

(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.

9.6.2.3 To minimize the risk of fire or explosion hazard in the handling of zirconium powders, the equipment and processes shall be designed by people knowledgeable in the hazards of zirconium powders.

9.6.2.4 Electrical Installations.

9.6.2.4.1 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.

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

9.6.3 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.

9.6.4 Housekeeping Practices.

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

9.6.4.2 Special attention shall be paid to powder accumulations in crevices and joints between walls and floors.

9.7 Fire Prevention and Fire Protection.

9.7.1 Fire Prevention. The provisions of Section 9.7 shall apply to all zirconium production processing, handling, and storage operations.

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

9.7.1.2 Sponge Collection.

9.7.1.2.1 Sponge discharged from dryers shall be collected in containers with a maximum capacity of 1814 kg (4000 lb).

9.7.1.2.2 The collection area shall be well-ventilated and free from other combustible materials.

9.7.1.3* Hot Work.

9.7.1.3.1 Hot-work permits shall be required in designated areas that contain exposed zirconium chips, powder, or sponge where hot work is conducted.

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

9.7.1.4* Other Molten Materials.

9.7.1.4.1 All containers used to receive molten metal, molten magnesium, molten magnesium chloride, or liquid sodium shall be cleaned and dried thoroughly before use.

9.7.1.4.2 All pieces of magnesium metal shall be clean and dry where charged to reduction furnaces.

9.7.1.5 Good housekeeping practices shall be maintained.

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

9.7.1.5.2 Supplies of materials in zirconium processing areas shall be limited to the amounts necessary for normal operation.

9.7.1.6 Ordinary Combustible Materials.

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

9.7.1.6.2 The requirement of 9.7.1.6.1 shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

9.7.1.7* Periodic Cleaning.

9.7.1.7.1 Periodic cleaning of zirconium sponge, chips, or powder from buildings and machinery shall be carried out as frequently as conditions warrant.

9.7.1.7.2 Sponge, chips, or powder shall be removed to a safe storage or disposal area.

9.7.1.8 Periodic Inspections.

9.7.1.8.1 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.

9.7.1.8.2 Records shall be kept of these inspections specified in 9.7.1.8.1.

9.7.1.9* Disposal of Ordinary Combustible Materials.

9.7.1.9.1 Ordinary combustible materials shall not be discarded in containers used for the collection of sponge, chips, or powder.

9.7.1.9.2 Floor sweepings from zirconium operations shall be permitted to contain small amounts of ordinary combustible materials.

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

9.7.1.11 Smoking shall not be permitted in areas where ignitable zirconium sponge, chips, or powder are present.

9.7.1.11.1 Areas where zirconium sponge, chips, or powder are present shall be posted with "No Smoking" signs.

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

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

9.7.1.13 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.

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

9.7.1.15 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.

9.7.1.16 Areas used for torch-cutting of massive pieces of scrap shall be kept free of combustible materials.

9.7.2* General Fire Protection.

9.7.2.1 A fire protection plan shall be provided for all areas where zirconium is processed, handled, used, and stored.

9.7.2.2* Sprinkler Protection.

9.7.2.2.1 Except under the conditions of 9.7.2.2.2, buildings or portions of buildings of noncombustible construction used principally for zirconium storage or handling shall not be permitted to be equipped with automatic sprinkler protection.

9.7.2.2.2 Sprinkler systems installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be permitted in areas where combustibles other than zirconium create a more severe hazard than the zirconium and where acceptable to an authority having jurisdiction who is knowledgeable of the hazards associated with zirconium.

9.7.2.3 If required by the authority having jurisdiction, automatic sprinkler protection installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*, shall be provided for offices, repair shops, and warehouses not used for the storage of zirconium sponge, powder, or chips.

9.7.2.4 As an alternative to the requirement of 9.7.2.3, a specially engineered fire protection system specifically designed to be compatible with the hazards present in the zirconium operation area shall be permitted to be installed in areas where combustible loading is essential to the process operation.

9.7.3 Extinguishing Agents and Application Techniques.

9.7.3.1 Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing zirconium fires shall be permitted.

(A) A supply of extinguishing agent for manual application shall be kept within easy reach of personnel while they are working with zirconium.

(B) The quantity of extinguishing agents shall be sufficient to contain anticipated fires.

9.7.3.2 Agents intended for manual application shall be kept in identified containers.

(A) Container lids shall be secured in place to prevent agent contamination and to keep the agent free of moisture.

(B) Where large quantities of agent are expected to be needed, a clean, dry shovel shall be provided with the container.

(C) Where small amounts of agent are needed, a hand scoop shall be provided with each container.

9.7.3.3 Portable or wheeled extinguishers approved for use on zirconium fires shall be permitted and shall be distributed in accordance with NFPA 10, *Standard for Portable Fire Extinguishers*.

9.7.3.4* Water-based or CO₂ extinguishers shall not be provided in areas containing zirconium sponge, chips, or powder.

9.7.3.4.1 CO₂ extinguishers for use on electrical fires shall be permitted in areas containing zirconium.

9.7.3.4.2 The CO₂ extinguishers specified in 9.7.3.4.1 shall be clearly marked "not for use on zirconium fires."

9.7.3.5 The following agents shall not be used as extinguishing agents on a zirconium fire because of adverse reaction:

- (1) Water
- (2) Foams
- (3) Halon
- (4) Carbon dioxide

9.7.3.6 An A:B:C dry-chemical extinguisher and a B:C dry-chemical extinguisher shall not be used as a zirconium fire extinguishing agent, but shall be permitted to be used on other classes of fires in the area where zirconium is present.

9.7.3.7* Dry sodium chloride, or other dry chemicals or compounds suitable for extinguishment or containment of zirconium fires, shall be permitted to be substituted for Class D fire extinguishers.

(A) The alternative agents specified in 9.7.3.7 shall be stored in a manner that ensures the agent's effectiveness.

(B) Shovels or scoops shall be kept readily available adjacent to the containers.

(C) All extinguishing agent storage areas shall be clearly identified.

9.7.3.8 Zirconium fines shall be segregated by storage in noncombustible drums.

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

(A) When feed is stopped, the equipment shall be kept in operation, unless the conditions of 9.7.3.9(B) exist.

(B) Where continued operation of equipment would cause the spread of fire, the equipment shall be stopped.

Chapter 10 Requirements for Combustible Metals Not Covered in Chapter 4 through Chapter 9

10.1 Building Construction.

10.1.1 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.

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

10.1.3 Building areas where combustible metal dusts might be present shall be designed so that all internal surfaces are accessible to facilitate cleaning.

10.1.3.1 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.

10.1.3.2 The annulus of all pipe, conduit, and ventilation penetrations shall be sealed.

10.1.3.3 Roofs.

10.1.3.3.1 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.

10.1.3.3.2 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.

10.1.3.4 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.

10.1.4 Roof decks and basements shall be watertight.

10.1.5* 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.

10.1.6 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 Fire Windows*.

10.1.7 Enclosed Passageways.

10.1.7.1* 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.

10.1.7.2 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*.

10.1.8 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.

10.1.9 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 who is knowledgeable of the hazards associated with the combustible metal.

10.2 Manufacturing and Processing.

10.2.1 Dust-Producing Operations.

10.2.1.1* 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.

10.2.1.2* 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.

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

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

10.2.1.4.1* 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.

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

10.2.1.4.3 Personnel protective clothing shall comply with Section 10.8.

10.2.1.4.4 The collector shall be designed to dissipate static electricity.

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

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

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

CAUTION: This dust collector can contain explosible dust.

10.2.1.7* 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.

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

Current Use: [Type of] Metal — Fire or Explosion Can Result with Other Metals

10.2.1.9* Cutting tools shall be designed for use with the metal being worked and shall be kept sharp.

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

10.2.1.11 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.

10.2.1.12 Nonflammable coolants shall be used for wet grinding, cutting, and sawing operations.

10.2.1.12.1 The coolant shall be filtered on a continuous basis.

10.2.1.12.2 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.

10.2.2 Powder Handling and Use.

10.2.2.1 Where metal powder or paste is used or handled, good housekeeping practices shall be maintained.

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

10.2.2.3 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.

10.2.2.4 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 Operation*.

10.2.2.5 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.

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

10.2.3* 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.

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

10.2.3.2 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.

10.2.3.3* To minimize the risk of fire or explosion hazards in the handling of dry metal powders, the equipment and processes shall be designed by people knowledgeable in the hazards of metal powders.

10.2.4 Melting and Casting Operations.

10.2.4.1* 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.

10.2.4.2 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.

10.2.4.3 Buildings used for the melting and casting of metals shall be noncombustible.

10.2.4.4 Floors shall be kept free of standing water.

10.2.4.5* All solid metal shall be thoroughly dried throughout by preheating or other methods prior to coming into contact with molten metal.

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

10.2.4.7 Fuel supply lines shall comply with NFPA 54, *National Fuel Gas Code*.

10.2.4.8 Use of flammable and combustible liquids shall comply with NFPA 30, *Flammable and Combustible Liquids Code*.

10.2.4.9 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.

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

10.2.4.11 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.

10.2.4.12 Pots and Crucibles.

10.2.4.12.1 Melting pots and crucibles shall be inspected regularly.

10.2.4.12.2 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.

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

10.2.4.14 Extreme care shall be exercised in pouring metal castings to avoid spillage.

10.2.4.15 All molds shall be thoroughly preheated before pouring.

10.2.4.16 Operators' Clothing.

10.2.4.16.1 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.

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

10.2.5 Combustible Dust Collection

10.2.5.1 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.

10.2.5.2 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*.

10.2.5.3 Ducts shall be designed to maintain a velocity that will 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).

10.2.5.4* Ducts shall be designed to handle a volumetric flow rate that maintains dust loads safely below the minimum explosible concentration (MEC).

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

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

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

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

10.2.5.9 Branch Ducts.

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

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

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

10.2.6 Combustible Metal Wet-Type Dust Collectors.

10.2.6.1 Exhaust Vent.

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

10.2.6.1.2 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.

10.2.6.2 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.

10.2.6.3* 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.

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

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

10.2.6.6* The dust collector shall be arranged so that the dust-laden airstream is thoroughly scrubbed by the liquid to achieve the desired efficiency.

10.2.6.7 The use of additional dry filter medium, either downstream or combined with a wet collector, shall not be permitted.

10.2.6.8* Sludge shall be removed from the collector on a regular schedule.

10.2.6.9 Removed sludge shall be stored in a covered, vented metal container.

10.2.7 Collector Sump Venting.

10.2.7.1* The sump of water wet-type dust collectors shall be ventilated from the top of the collector at all times.

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

10.2.7.3 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.

10.2.8 Power Supply.

10.2.8.1 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.

10.2.8.2 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.

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

10.2.9.1 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.

10.2.9.2 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.

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

10.2.10 Combustible Metal Dry-Type Dust Collectors.

10.2.10.1 Electrostatic and media collectors shall not be used.

10.2.10.2* Dry-type dust collectors shall be fabricated of conductive material and grounded and bonded.

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

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

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

10.2.10.6 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.

10.2.10.7* Dry collectors used for combustible metal dust shall be provided with deflagration vents.

10.2.10.8 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.

10.2.10.9 Repairs.

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

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

10.2.10.10 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.

10.2.10.11 The dust collector shall be arranged so that contact between dust particles and parts moving at high speeds shall be prevented.

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

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

10.2.12 Heating and Cooling of Powder Production Buildings.

10.2.12.1 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.

10.2.12.2 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.

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

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

10.2.12.5 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.

10.2.12.6 The requirements of 10.2.12.1 through 10.2.12.5 shall not apply to areas where metal is melted.

10.2.13 Fittings used on compressed-air and inert gas-line outlets shall not be interchangeable to prevent potential explosions caused by inadvertently using compressed air in place of low-pressure inert gas.

10.2.14 Water leakage inside or into any building where the water can contact metal powder shall be prevented to avoid possible water-metal reactions.

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

10.3 Storage.**10.3.1 Storage of Combustible Scrap Metal.**

10.3.1.1 Subsection 10.3.1 shall apply to the storage of scrap metal in the form of solids, chips, turnings, swarf, or other fine particles.

10.3.1.2 Buildings used for the indoor storage of metal scrap shall be of noncombustible construction.

10.3.1.3 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 so as to avoid the fines becoming wet.

10.3.1.4* 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.

10.3.1.5 Storage of dry scrap in quantities greater than 1.4 m³ (50 ft³) [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).

10.3.1.6 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.

10.3.1.7 Solid metal scrap, such as clippings and castings, shall be stored in noncombustible bins or containers.

10.3.1.8 The storage of oily rags, packing materials, and similar combustibles shall be prohibited in storage bins or areas that store solid metal scrap.

10.3.1.9 The use of automatic sprinklers in metal scrap storage buildings or areas shall be prohibited.

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

10.3.2 Storage of Alkali Metals.

10.3.2.1* Alkali metals shall be permitted to be stored in shipping containers meeting the requirements of 49 CFR, 100-199, or in clean, moisture-free, compatible, nonreactive, metal-sealed containers dedicated for the storage of alkali metals.

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

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

10.3.2.4 Alkali metals containers shall not be stored outside, except under the conditions of 10.3.2.5.

10.3.2.5 Alkali metals fire residues shall be permitted to be stored outside where placed in a double-steel, overpack drum and inspected daily.

10.3.3 Solid Alkali Metals.

10.3.3.1 Solid alkali metals shall be stored only on a ground floor.

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

10.3.3.3 The solid alkali metals storage area shall be isolated from other areas so that water cannot enter by spray or drainage from automatic sprinkler systems or any other water source.

10.3.3.4 Container Storage Arrangement.

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

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

10.3.3.4.3 Containers on pallets and not stored in racks shall be stacked in a stable manner and shall not exceed three pallets in height.

10.3.3.4.4 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.

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

10.3.4 Molten Metal Storage. Molten metal storage shall be in closed systems and in separate buildings or portions of buildings designed by competent designers solely for that purpose.

10.3.5 Storage of Combustible Metal Powder.

10.3.5.1 Buildings used to store metal powder shall be of noncombustible construction.

10.3.5.2 The use of automatic sprinklers in metal powder storage buildings shall be prohibited.

10.3.5.3 Metal powder shall be kept separated from other ordinary combustibles or incompatible materials.

10.3.5.4 Metal powder shall be stored in closed steel drums or other closed noncombustible containers.

10.3.5.5 Metal powder storage areas shall be kept dry and checked for water leakage.

10.3.5.6* All areas used for the storage of metal powder shall be classified in accordance with Article 500 of NFPA 70, *National Electrical Code*.

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

10.3.5.8* Where metal powder in drums is stacked for storage, the maximum height shall not exceed 3.7 m (12 ft).

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

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

10.3.6* Storage of Other Metal Products.

10.3.6.1 Storage in quantities greater than 1.4 m³ (50 ft³) shall be separated from storage of other materials that either are combustible or in combustible containers by aisles with a minimum width equal to the height of the piles of metal products.

10.3.6.2 Metal products stored in quantities greater than 28 m³ (989 ft³) shall be separated into piles, each not larger than 28 m³ (989 ft³), with the minimum aisle width equal to the height of the piles but not less than 3.1 m (10 ft).

10.3.6.3* The storage area shall be protected by automatic sprinklers in any of the following situations:

- (1) Where storage in quantities greater than 28 m³ (1000 ft³) is contained in a building of combustible construction
- (2) Where metal products are packed in combustible crates or cartons
- (3) Where other combustible storage is within 9 m (30 ft) of the metal

10.4 Housekeeping.

10.4.1 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.

10.4.2 Cleanup Procedures for Fugitive Dust Accumulations.

10.4.2.1* Fugitive dust shall not be allowed to accumulate.

10.4.2.2 Periodic cleanup of fugitive dusts shall be accomplished by using conductive, nonsparking scoops and soft brooms or brushes that have natural fiber bristles.

10.4.3* Vacuum Cleaning.

10.4.3.1 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.

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

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

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

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

10.4.3.5.1 Assembled components shall be conductive and bonded where necessary.

10.4.3.5.2 Periodic tests for continuity shall be performed.

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

10.4.4 Compressed-Air Cleaning Requirements. Compressed-air blowdown shall not be permitted, unless the conditions of 10.4.5 are met.

10.4.5 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.

10.4.6 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.

10.4.7 Cleaning Frequency.

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

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

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

10.4.9 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.

10.4.10 Regular, periodic cleaning of fugitive metal dust from buildings and machinery shall be carried out as frequently as conditions warrant.

10.4.11 Fugitive metal dust shall be removed to a designated storage or disposal area.

10.4.12 Inspections.

10.4.12.1 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.

10.4.12.2 Records shall be kept of the inspections specified in 10.4.12.1.

10.4.13 Ordinary combustible materials shall not be discarded in containers used for the collection of combustible metal dust or scrap.

10.4.14 Designated containers shall be used for the collection of fugitive metal dust.

10.4.15 Combustible or flammable liquid accidental spills shall be cleaned up immediately.

10.5 Ignition Sources.

10.5.1* Control of Ignition Sources. Open flames, electric or gas cutting or welding, or other spark-producing operations, shall not be permitted in the section of the building where combustible metal dust is produced or handled, unless the conditions in 10.5.2, 10.5.3, 10.5.4, 10.5.5, 10.5.6, 10.5.7, and 10.5.8 are met.

10.5.2 Smoking by employees or visitors is prohibited about the premises adjacent to or within any building in which combustible metal dust is present.

10.5.3 Propellant-actuated, air-actuated, or gas-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 cleaned.

10.5.4* Nonsparking tools shall be used when repairs or adjustments are made on or around any machinery or apparatus where combustible dust is present.

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

10.5.6 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*.

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

(A) Synthetic bristles shall not be used.

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

10.5.8 Dry metal sweepings shall not be returned to the main process stream for processing.

10.5.9 Smoking.

10.5.9.1 Smoking shall be permitted only in designated areas separated from production or storage areas.

10.5.9.2 Areas where smoking is prohibited shall be posted with "No Smoking" signs.

10.6* Electrical.

10.6.1 Grounding. All process equipment and all building steel shall be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

10.6.2 Manufacturing and processing areas shall be classified, where applicable, in accordance with Article 500 of NFPA 70, *National Electrical Code*.

10.6.3 Electrical Equipment Maintenance.

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

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

10.6.4 Flashlights, electronic devices, and other portable electrical equipment shall be listed for use in hazardous locations.

10.6.5 All electrical equipment and wiring shall comply with NFPA 70, *National Electrical Code*.

10.6.6* Wet solvent milling areas or other areas where flammable or combustible liquids are present shall be classified, where applicable, in accordance with NFPA 70, *National Electrical Code*.

10.7* Hot Work.

10.7.1 Hot-work permits shall be required in designated areas that contain combustible metal fines, dust, or sponge where hot work is conducted.

10.7.2 All hot-work areas that require a permit shall be thoroughly cleaned of exposed fines, dust, or sponge before hot work is performed.

10.8 Personal Protective Equipment.

10.8.1 Outer clothing shall be clean, flame retardant, and nonstatic-generating where combustible metal dust is present.

10.8.1.1 Outer clothing shall be designed to be removable.

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

10.8.2 Work clothing shall be designed to minimize the accumulations of combustible metal dust (for example, trousers shall not have cuffs).

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

10.8.4* Clothing Fires.

10.8.4.1 Emergency procedures for handling clothing fires shall be established.

10.8.4.2 If deluge showers are installed, they shall be located such that water from the shower cannot enter dry metal powder-processing and handling areas.

10.8.5* Emergency Procedures.

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

10.8.5.2 All employees shall be trained in the emergency procedures.

10.9* Fire Fighting, Prevention, and Procedures.

10.9.1 Fire Extinguishment. Extinguishing activities shall be conducted in a manner so as not to create an airborne dust cloud.

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

10.9.3 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 work practices are being followed.

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

10.9.3.2 The inspection shall be conducted by a person(s) knowledgeable in the processes, and the findings and recommendations shall be recorded.

10.9.4 Maintenance. Regular and periodic maintenance checks and calibration on equipment critical to employee safety and plant operation shall be performed.

10.9.5 Portable Fire Extinguishers.

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

10.9.5.2 Water-based, halogenated compounds, or CO₂ extinguishers shall not be provided in areas containing combustible metals.

10.9.5.3 Portable extinguishers to be used on metal fires shall be approved for use on Class D fires.

10.9.5.3.1 As approved by the authority having jurisdiction, other dry chemicals or compounds suitable for extinguishment of fires shall be permitted to be substituted for Class D fire extinguishers.

10.9.5.3.2 The alternative agents specified in 10.9.5.3.1 shall be stored in a manner that ensures the agents' effectiveness.

10.9.5.3.3 Shovels or scoops shall be kept available adjacent to the containers.

10.9.5.3.4 All extinguishing agent storage areas shall be clearly identified.

10.9.5.4 All A:B:C dry-chemical extinguishers shall be identified as "prohibited for" or "unsuitable for" use on combustible metal fires.

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.1.1.1 Under the 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, 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 these burning characteristics. The manufacturer or technical personnel knowledgeable of the hazards associated with the metal should be consulted to characterize the hazards of the metal. (See Table A.1.1.3.)

Table A.1.1.3 Characteristics of Metal

	Solid	Dust	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	X		660	2452	555								
Aluminum dust		X				650	750	50	85	290	5	Yes	
Barium	X		725	1140	175								
Bronze powder		X								31			
Calcium	X		824	1440	704								
Calcium/silicon alumina		X								200			
Hafnium	X	X	2223	5399									
Iron	X	X	1535	3000	930					50			
Ferrochrome		X								86			
Ferromanganese		X								84			
Lithium	X		186	1336	180								
Magnesium	X		650	1110	623								
Magnesium dust		X											
Manganese		X											
Molybdenum		X											
Niobium		X											
Plutonium	X		640	3315	600								
Potassium	X		62	760	69								
Silicon		X								126			
Sodium	X		98	880	115								

(continues)

Table A.1.1.3 *Continued*

	Solid	Dust	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
Strontium	X		774	1150	720								
Tantalum	X												
Tantalum powder		X											
Thorium	X		1845	4500	500								
Titanium	X		1727	3260	1593								
Titanium dust		X											
Uranium	X		1132	3815	3815								
Zinc	X		419	907	900								
Zinc dust		X											
Zirconium	X		1830	3577	1400								
Zirconium powder		X											

Notes:

Data in table are meant to be representative. Actual test data should be used to characterize specific metals.

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:

1 g/m³ = 6.24 × 10⁻⁵ lb/ft³

°F = 1.8 (°C) + 32

1 kJ = 0.95 Btu; 1 mJ = 0.95 × 10⁻⁶ Btu

1 bar · m/s = 328 (kPa · ft)/s

A.1.1.5 Regulations for the domestic shipment of dangerous goods (lithium and lithium alloy materials are so classified) are issued by the U.S. 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.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; build-

ing 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 will vary depending on the type of combustible dust, conditions, amount of material present, and processing methods used.

A dust explosion requires the four following 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 so as to determine the following data:

- (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 data can be determined by optional testing:

- (1) Dust cloud ignition temperature
- (2) Maximum permissible oxygen content to prevent ignition
- (3) Electrical resistivity measurement

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 (includes 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 autoignition if not cooled over a period of time

A.3.3.13 Fire-Resistive. The requirements are described in NFPA 220, *Standard on Types of Building Construction*.

A.3.3.16 Heavy Casting. Castings less than 11.3 kg (25 lb) are considered light castings.

A.3.3.18 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.3.3.21.2 Combustible Metal. See A.1.1.3 for further information on determining the characteristics of metals.

A.3.3.22 Minimum Explosible Concentration (MEC). 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.3.3.23 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.3.3.25.1 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 same precautions described in this standard should be observed.

A.3.3.25.4 Combustible Metal Powder. See NFPA 499, *Recommended Practice for 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.3.3.26 Powder Production Plant. Facilities or buildings in which powder or combustible dust is produced incidental to operations are not considered a powder production plant.

A.3.3.27 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, 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 address the problems of combustible liquids and vapors.

A.3.3.29 Spark-Resistant Material. See AMCA Standard 99-1401-66-91, “Classifications for Spark-Resistant Construction,” for additional information.

A.3.3.30 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.3.3.35 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 SF₆ and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern.

A.4.1.2.10 For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.4.1.3.2 See Section 5.11 and Chapter 28 of NFPA 101.

A.4.1.4.1 For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.4.1.5.1 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.1.6.2 For additional information on classification of dusty locations, see NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A.4.1.8.1.3 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.4.1.8.2.3 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.4.1.8.2.4.1 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.4.1.9.8.2 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.1.9.8.3 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.4.1.9.8.5 Typical margins of safety used for pneumatic dust handling are 25 percent to 50 percent of the MEC. Published data indicates an MEC of 45 g/m³ (0.045 oz/ft³) 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 necessarily 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.4.1.9.8.6 For information on spacing and sizing of ductwork deflagration vents, see NFPA 68, *Guide for Venting of Deflagrations*.

A.4.1.9.9.1 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 that forms 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.4.1.9.9.2 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.4.1.9.10.1 Information on spark-resistant fans and blowers can be found in AMCA Standard No. 99-1401-66-91, "Classifications for Spark-Resistant Construction."

A.4.1.9.10.4 Ultimately, all fans or blowers in dust collection systems accumulate sufficient powder to become a potential explosion hazard.

A.4.1.9.10.5 Fans or blowers can also be provided with vibration-indicating devices, arranged to sound an alarm or to provide shutdown, or both, in the event of blade or rotor imbalance or bearing or drive problems.

A.4.1.10.1 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 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, *Guide for Venting of Deflagrations*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.4.1.10.1.2 See NFPA 68, *Guide for Venting of Deflagrations*, for the method to calculate the length of a fireball issuing from a vented collector.

A.4.1.10.1.5 For information on precautions for static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.1.10.1.7 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, *Guide for Venting of Deflagrations*. Dust collectors, when provided by a manufacturer, seldom have properly sized venting to handle a combustible aluminum dust explosion.

A.4.1.10.3 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.4.1.11.4 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.4.2.3 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 these reasons, the same precautions must be observed as for normal grades of powder.

A.4.2.4.1 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.4.2.4.1.1 See A.4.2.4.1.

A.4.2.4.1.2 See A.4.2.4.1.

A.4.2.4.1.5 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 the flammable gas or vapor, even at concentrations less than their lower flammable limit (LFL), will not only add to the violence of the dust-air combustion but will drastically reduce the ignition energy. In such cases, electrical equipment should be specified that is suitable for simultaneous exposure to both the Class I (flammable gas) and the Class II (combustible dust) hazards.

A.4.2.4.2.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.2.4.2.4 For additional information on classification of areas containing solvent vapors, see NFPA 497, *Recommended Practice for the Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A.4.2.5 See Figure A.4.2.5(a) and Figure A.4.2.5(b) for examples of bag dump-station dust collection.

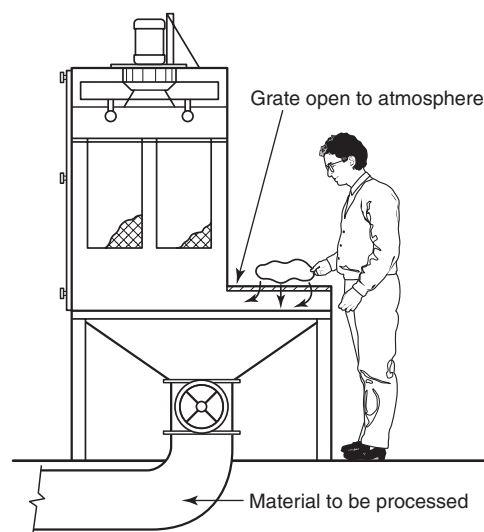


FIGURE A.4.2.5(a) Example of Unacceptable Manual Bag Dump Station (Exposes Operator to Potential Fire or Explosion, or Both).

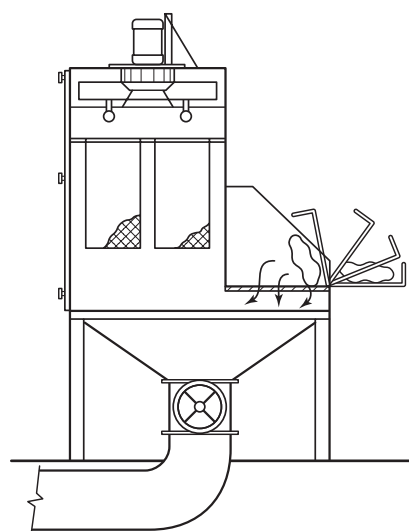


FIGURE A.4.2.5(b) Example of Acceptable Station (Automated Bag Dump Operation Only).

A.4.3.1 There are two recognized methods of collecting aluminum dust in industrial operations. They are wet dust collectors, which can be located indoors near the point of dust generation, or dry-type collectors located outdoors and as close as possible to the point of dust generation.

A.4.3.2.1 Minimum explosible concentrations 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 minimum explosible concentration in the conveying system, the suspension can pass through the flammable range in the collector at the end of the system.

A.4.3.2.3 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.4.3.2.5 Figure A.4.3.2.5 is an example of a media-type dust collector. The figure shows major system components.

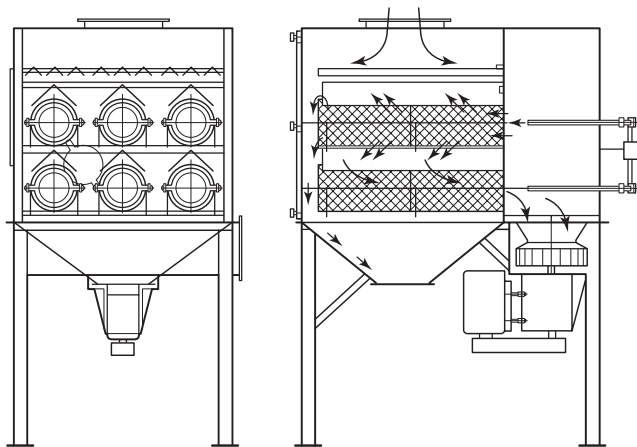


FIGURE A.4.3.2.5 Example of a Fixed Media-Type Dust Collector.

A.4.3.2.5.1 See Figure A.4.3.2.5.1.

A.4.3.2.5.2 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 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 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.

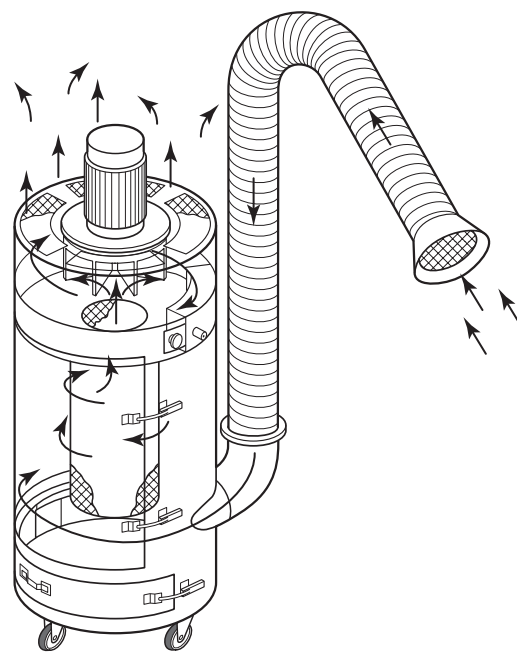


FIGURE A.4.3.2.5.1 Example of a Portable Media-Type Dust Collector.

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, *Guide for Venting of Deflagrations*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.4.3.2.5.3 For the method to calculate the length of a fire-ball issuing from a vented collector, see NFPA 68, *Guide for Venting of Deflagrations*.

A.4.3.2.6 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 the article by H. S. Eisner, "Aluminum and the Gas Ignition Risk."

A.4.3.3.3 The 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 for dust clouds ranged upwards from 15 mJ, whereas minimum ignition energies for dust layers ranged upwards from 15 mJ. Ignition temperatures ranged upwards from 320°C (608°F). Minimum explosive

concentrations ranged upwards from 40 g/m^3 (0.040 oz/ft^3). Maximum explosion pressures can exceed 620 kPag (90 psig).

A.4.3.3.4 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.4.3.3.6 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.3.4.1 The reaction of water and aluminum produces hydrogen. Hydrogen is extremely flammable and is very easy to ignite. It should not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A.4.3.4.2 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 cake or a sponge-like deposit (sludge), which is highly combustible, on the inner wall of the exhaust duct.

A.4.3.4.4 Refer to Figure A.4.3.4.4(a), Figure A.4.3.4.4(b), and Figure A.4.3.4.4(c) for examples of liquid precipitation collectors.

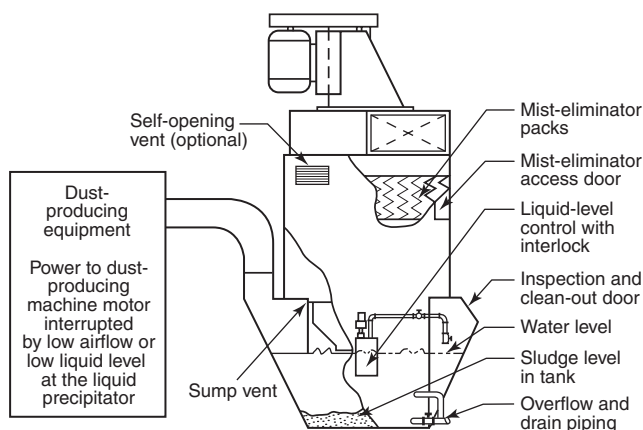


FIGURE A.4.3.4.4(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

A.4.3.4.5 It should be remembered that wetted dust that is not submerged under a cover of water is highly flammable and very dangerous.

A.4.3.4.6.1 The reaction of aluminum with water produces hydrogen, which is highly flammable.

A.4.3.4.8.2 Containers preferably should not hold more than 23 kg (50 lb) each.

A.4.3.4.8.4 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. 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 aluminum powder plants.

A.4.3.5.2 Some collector bags or other types of media or screens have fine, noninsulated wire enmeshed into or woven

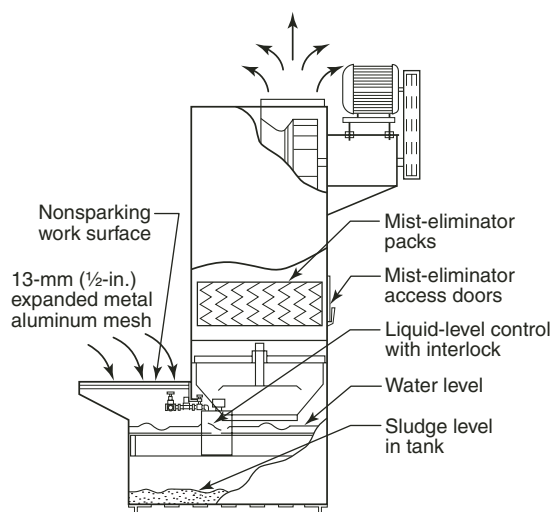


FIGURE A.4.3.4.4(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

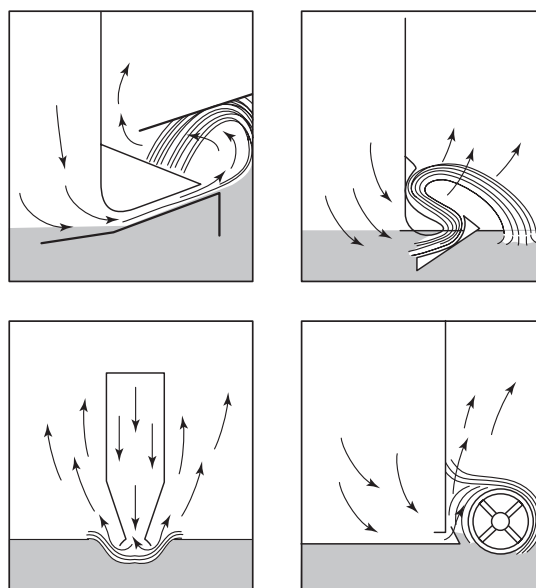


FIGURE A.4.3.4.4(c) Five Methods of Precipitating Dust in Precipitators.

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.4.3.5.6 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, *Guide for Venting of Deflagrations*. Dust collectors, when provided by a manufacturer, seldom have properly sized venting to handle a combustible aluminum dust explosion.

A.4.3.7.1 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.4.3.7.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.3.8.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.4.2.1 Once ignition has occurred either in a cloud suspension or 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 this reason, good housekeeping in all areas that handle dust is vitally important.

A.4.4.3 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 200 psig (1380 kPag). 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 ant flashback valves.

A.4.4.3.2 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.4.4.3.4 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.4.5.1 Since 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 4.5.2 should be followed if the fire is to be controlled quickly. This is especially true with regard to the application of the extinguishing material, as 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.4.5.2.1 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 (see A.4.5.2.6.3).

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.4.5.2.4 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.4.5.2.6.3 Class B extinguishing agents will usually greatly accelerate combustible aluminum dust fires and can cause the burning metal to explode.

A.4.5.3 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 very 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.4.5.3.2 Recent experience has shown that some types of water-based foam extinguishing agents can be effective on solvent fires.

A.4.5.3.3.1 Reignition can occur due to high localized heat or spontaneous heating. To avoid reignition, the residual material should be immediately smothered.

A.4.5.3.3.3 Materials preferably should be handled in quantities of not more than 11 L (3 gal) each in 19-L (5-gal) containers.

A.4.5.3.4.6 For guidance on design criteria for fire flow containment, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.4.5.4.1.1 For the automatic sprinkler provisions for storage and use of flammable and combustible liquids, see NFPA 30, *Flammable and Combustible Liquids Code*.

A.4.5.5.3 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.4.5.6 Employee health and safety in operations depend on the recognition of actual or potential hazards, the control or elimination of these hazards, and the training of employees on safe working procedures.

A.4.5.7.3 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 "Aluminum and the Gas Ignition Risk," by H. S. Eisner, and "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction." (See *Annex I*.)

A.4.6.2.3 Safety shoes that meet the following guidelines should be worn by all operating personnel, except those persons who are required to work on electrical circuits or equipment. (See ANSI Z41, *Personal Protection — Protective Footwear*, for information.)

The following are important elements for safe shoes:

- (1) Soles should be resistant to embedding particles and to petroleum solvents, if used.
- (2) Soles and heels should be attached by sewing or pegging.
- (3) Nails, metal cleats, or metal plates should not be used.
- (4) Safety toe caps should be completely covered with a scuff-resistant material.
- (5) Soles and heels should be static-dissipating.

A.4.6.2.4 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.4.6.3.2 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.5.1 Finely divided, dry lithium and finely divided lithium dispersed in a flammable liquid can exhibit pyrophoric properties. Prior to handling these materials, the vendor of the lithium, lithium alloy, or lithium 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 lithium and lithium 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 lithium, and dispersions of some other 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, 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 address the problems of combustible liquids and vapors.

A.5.1.1 Lithium reacts with moisture from any available source, such as concrete, the atmosphere, and human skin. The degree and speed of the reaction varies with the conditions; therefore, the best approach is to take precautions to keep moisture away from lithium.

A.5.1.2 Small facilities isolated from other facilities under the same ownership are ideal for handling and processing lithium. In the event of an uncontrolled lithium emergency, property damage would be comparatively reduced.

A.5.1.3 Lithium fire residue products can include metallic lithium, lithium nitride, lithium oxide, or lithium hydroxide, which can absorb moisture.

A.5.1.3.1 Once a lithium fire is extinguished, lithium is usually still present in sufficient quantity to create adverse reactions and exhibit the burning characteristics of lithium. Lithium fire residues can include other reactive components. These residues can react with each other and cause reignition. 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.5.2 Consideration should be given to automatic fire detection systems within lithium 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 with 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 Nonslip surfaces should be provided due to the potential presence of mineral oil on the floor. Gratings should be used only where containment provisions have been provided below the area or where access can be restricted below the area.

A.5.2.2.1 Laboratories, bathrooms, and other areas not dedicated to the processing of lithium can have water leaks. Consideration needs to be given to preventing water from such leaks from entering the lithium processing areas, creating fire and explosion hazards.

A.5.3.1.4 See also 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 When evaluating the amounts needed for process use, the risks and fire exposures should be evaluated with other processing requirements. Lithium in containers staged for melting should be considered process vessels.

A.5.3.2.1 Dispersions of lithium, and dispersions of some other 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, 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 address the problems of combustible liquids and vapors.

A.5.3.2.3 Solid lithium is supplied in a variety of forms (for example, 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, lithium 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 lithium intended to be used should be removed.

A.5.3.3.3 Molten lithium will react exothermically with moisture and iron oxide. When metal drums are to be filled with molten lithium, they are hydrostatically tested to ensure no leaks. In the 1970s, there were a few instances where a 208-L (55-gal) steel drum was being filled with molten lithium and there was a sudden buildup of pressure in the drum. Since the drum was heated in excess of 100°C (212°F) and purged with argon for 8 hours, it is unlikely that there was any residual moisture in the drum from the hydrostatic testing. It is possible that iron oxide was present. Iron oxide will react exothermically with molten lithium. A program of visual inspection of the inside of the drum was started, and there were no further incidents.

A.5.4.1.1 Lithium is shipped from lithium manufacturers in DOT- or HM 181-approved containers that should continue to act as storage containers. Containers should be sealed to remain airtight, with the lithium coated with mineral oil or packed under an argon cover. Containers used to store lithium under mineral oil for long-term storage (over 3 months) should be inverted to redistribute the mineral oil covering the lithium. Containers packed under an argon cover should be checked regularly to verify the integrity of the container seal. When lithium is returned to any shipping container, the protective method used by the manufacturer should be duplicated.

A.5.4.1.3 Lithium is 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

Oxalic acid, phenol and organic acid mixtures, or compounds such as paint strippers or metal cleaners are also reactive and should not be stored in the vicinity of lithium.

A.5.5.1 Because of the unique nature of lithium fires, a comprehensive fire protection plan is necessary where lithium is processed, handled, used, or stored. The plan should include specific actions in the event of a lithium fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

This plan should pay special attention to the extreme hazards associated with lithium–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 lithium 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 lithium fires can affect local environmental quality conditions, an exhaust treatment system should be provided.

Properly trained personnel who work with lithium know its hazards. Such personnel will have the greatest chance to extinguish a lithium fire in its incipient stage. Training should include sufficient information to determine if extinguishment can be accomplished safely and effectively.

Lithium at room temperature in the presence of incompatible materials can reach its melting point and its autoignition temperature.

The degree of reaction and the amount of time to produce the melting point and autoignition temperature vary with conditions surrounding the fire, with the temperature of the exposed lithium being the major factor. At low temperatures or temperatures within a few degrees of lithium's melting point, the reaction is slower with reduced intensity. At higher temperatures, the reaction is accelerated and more intense.

When fighting a lithium fire, it is very important that fire fighters be aware of the dangers of burning lithium. When molten lithium reacts with materials such as water or flammable or combustible liquids or gases, molten lithium can be ejected for a considerable distance. The severity of lithium reactions varies with a multitude of conditions.

Lithium in contact with moisture and air forms lithium hydroxide and lithium oxide, which will cause caustic burns without adequate personal protective equipment.

A.5.5.1.2 The reaction of lithium, especially burning lithium, with water is extremely hazardous. Where combustible loading in areas used for lithium processing is determined by the authority having jurisdiction to require sprinkler protection, consideration should be given to the installation of preaction sprinkler systems to reduce the opportunity for accidental discharge.

A.5.5.1.3 Where the presence of non-water-reactive, combustible materials has been determined to require sprinkler protection, the quantities of lithium exposed to sprinkler action and the ability of workers to quickly secure the exposed

lithium (for example, place the lid back on the drum to reseal the container) also need to be evaluated.

A.5.5.1.5 If dry-chemical extinguishing systems are used, see NFPA 17, *Standard for Dry Chemical Extinguishing Systems*.

A.5.5.2.1 Several agents (for example, copper powder, graphite-based agents, and lith-x) have been tested on lithium fires and found to be successful with varying results. These agents all form a crust of varying durability over the fuel, but due to molten lithium's fluid properties, lithium is subject to burn-throughs. Copper powder formed the most durable crust of all these effective fire-fighting agents.

Low-density agents were found to be difficult to apply in windy conditions, resulting in decreased effective range of extinguisher, reduced visibility, and larger amounts of agent needed.

Testing indicates that the amount of agent needed depends on several factors. Small-scale lithium fires require the use of an acceptable ratio of extinguishing agents. Larger fires can require dramatically larger ratios. The acceptable ratio varies, depending on the agent selected.

Lithium, with its low density, will float on solid or liquid. Extinguishing agents will tend to sink in molten lithium; therefore, as the depth of fuel increases, the amount of agent needed will increase. Extended testing and evaluation of lithium fires indicates that the amount of agent needed is not based on weight of agent per weight of fuel, but should be based on depth and surface area of involved fuel per weight of agent.

The lower the temperature of the lithium, the less heat will be required to be drawn from the lithium to reduce reactions and, therefore, reduce the amount of agent needed.

A.5.5.2.3 In cases where the weight of the lithium hazard is small and well defined, portable or wheeled extinguishers should be distributed so that at least one is located within 22.7 m (75 ft) of the hazard and additional extinguishers can be readily available.

The recommendation for use of wheeled extinguishers where large amounts of lithium are found is based on the following:

- (1) One or two individuals can deliver large amounts of agent in a relatively short period of time.
- (2) Being highly mobile, wheeled extinguishers can be situated to provide more complete coverage of any facility.
- (3) Wheeled units protecting other areas that might not be affected in the emergency can be brought to the scene.

A.5.5.2.5 Dry-chemical agents should not be used on a lithium fire. Testing indicated that a B:C dry chemical was not an effective lithium-fire extinguishing agent, although it exhibited the least amount of adverse reaction with lithium.

A.5.5.2.6 Many common extinguishing agents and extinguisher expelling gases, when exposed to burning lithium, exhibit high reactivity. The degree of reactivity depends on a wide range of variables, such as temperature of the fire and other chemical compounds reacting with the lithium. For example, nitrogen, commonly used to expel dry-powder agent, does not exhibit a high degree of reactivity until the temperature of the fire increases.

Testing has indicated that carbon dioxide and nitrogen, commonly used as extinguisher expellant gases, are reactive to lithium at higher temperatures. Argon gas, being nonreactive to lithium, can be used successfully as a substitute.

If lithium is involved in a multiclass fire and agents that are reactive to lithium (for example, water, AFFF, and halon) are used, the effects of the reaction should be expected and preparations for the reaction should be made. Unmanned delivery techniques and any available physical protection should be used.

A.5.5.3.1 Burning lithium will burn through material used in the construction of most fire fighter protective clothing. Some features (for example, heavy quilted lining and aluminized outer shell) can reduce this risk. The self-contained breathing apparatus (SCBA) face piece eye protection worn by fire fighters adequately protects against the impacts of a lithium fire, with the exception of the intense light given off by burning lithium. (See NFPA 1500, *Standard on Fire Department Occupational Safety and Health Program*.)

A.5.5.3.2 Specific testing has indicated that white light levels emitted from burning lithium exceed recommended levels. Extended lithium fire experience has shown that this intense light can cause serious damage to unprotected eyes.

A clip-on adapter over an SCBA face piece with a shaded glass lens equivalent to a No. 6 welding lens has been used very successfully to reduce such hazards. A darker lens tends to obstruct the fire fighter's view to an unacceptable degree.

A.5.5.4.1.1 Full face shields, preferably shaded shields, should be made readily available in areas where lithium fires are likely to occur. These shields will provide adequate protection against small incipient-stage lithium fires.

A.5.5.5.1 One of the greatest dangers to fire fighters is the splattering effect of burning lithium. Molten lithium is very fluid and easily spread; therefore, extreme care needs to be taken when applying fire-fighting agent. The force used to deliver agent from an extinguisher can easily spread lithium particles; therefore, delivery technique is very important. If direct agent application becomes hazardous, indirect application techniques should be used. Deflecting agent off another object or directing the agent stream above the hazard and letting the agent fall by gravity can be effective.

A.5.5.5.2 Forming a crust over burning lithium reduces the available oxygen and eliminates exothermic reactions. Extinguishing agent should first be applied to the white-hot burning areas, then evenly applied to the mass, controlling the flow to form an oxygen-depleting crust. Since lithium tends to flow easily through any weak spots, agents should be applied evenly to construct a continuous crust. If lithium surfaces, additional agent should be applied to strengthen the crust.

Actual crust formation is created by the ability of some powdered agents to absorb heat from the lithium. In the case of copper powder, a lithium-copper alloy is formed as heat is absorbed from the lithium. Once the crust is formed, the temperature of the lithium decreases and exothermic reactions are reduced. Extreme care should be taken to ensure the crust is not disturbed or broken until the temperature of the lithium is decreased to the point where resolidification occurs.

A.5.6.1 Lithium in contact with moisture forms lithium hydroxide and lithium oxide, which will cause caustic burns. Lithium 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 lithium are significantly greater than those of handling solid lithium 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.6.1.4.3 See NFPA 68, *Guide for Venting of Deflagrations*.

A.6.1.5 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*.

A.6.2.1 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, as they 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.6.2.1.1.2 Since 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.6.2.1.2 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.6.2.1.4 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 SF₆ and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern.

A.6.2.2 Heat treating of magnesium has associated fire risks. To retard ignition of magnesium, mixtures of sulfur dioxide (SO₂), sulfur hexafluoride with carbon dioxide (SF₆/CO₂), helium (He), and argon (Ar) with air is recommended in heat-treating furnaces operating above 399°C (750°F).

A.6.2.2.3 See NFPA 86, *Standard for Ovens and Furnaces*.

A.6.2.2.7 Extreme care should be taken when heat treating aluminum that contains magnesium alloys, since 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.6.2.2.9 Heating magnesium in the presence of oxidizers can result in combustion. Special salt fluxes can be safely used for dip-brazing of magnesium.

A.6.2.2.10 Magnesium and aluminum form a eutectic alloy with considerably lower melting temperatures and autoignition temperatures than either parent metal.

A.6.2.2.11 There is a potential for a thermite reaction between magnesium, magnesium alloys, and iron oxide at elevated temperatures.

A.6.3.1 Flashing of chips during machining should be minimized by any of the following methods:

- (1) Keep the surface speed below 1.5 m/s (300 ft/min) or above 11 m/s (2200 ft/min).
- (2) Increase the feed rate from 0.02 mm to 0.25 mm (0.0008 in. to 0.010 in.) per revolution.
- (3) Control the relative humidity in the machining area to 45 percent or lower at 21°C (70°F) room temperature.
- (4) Apply a coolant.

A.6.3.1.2 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 sand-wich sections.

A.6.3.2.4.1 Interaction between magnesium 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.4.3.4.4(a), Figure A.4.3.4.4(b), and Figure A.4.3.4.4(c).]

A.6.3.2.4.2 See Figure 4-14, Range of Particle Size, Concentration, and Collector Performance, in “Industrial Ventilation: A Manual of Recommended Practice.” 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/ft³) of air, which is the minimum explosible concentration (MEC).

Minimum explosible concentrations 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.6.3.2.4.10 Interaction between magnesium 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.6.3.2.5.6 See NFPA 68, *Guide for Venting of Deflagrations*, for guidance on explosion venting.

A.6.3.3.3 Standard commercial industrial vacuum cleaners should not be used, as they are not safe for use with magnesium.

A.6.3.4.1 See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, for guidance on classified areas for Class II materials.

A.6.3.5 See NFPA 77, *Recommended Practice on Static Electricity*.

A.6.3.6.3 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.6.3.6.4 Special precautions are necessary to prevent ignitions while dressing 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.6.4.1.4 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.6.4.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.6.4.2.3 Bearings located outside of 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. Bearings should be located outside the air volume containing magnesium dust.

A.6.5.1.1 Special attention is necessary to ensure that the magnesium powder is not exposed to moisture.

A.6.5.2.2 Completely inert gas cannot be used as an inerting medium, since 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.6.5.2.5 Higher conveying velocities are more desirable and increase safety.

A.6.5.3.1 For information on explosion vents, see NFPA 68, *Guide for Venting of Deflagrations*. Ductwork vent spacing guidelines in NFPA 68 do not apply to K_{St} values greater than 300 bar·m/s.

A.6.5.3.2 See NFPA 69, *Standard on Explosion Prevention Systems*.

A.6.5.3.6 See NFPA 77, *Recommended Practice on Static Electricity*.

A.6.5.4.1 Information on spark-resistant fans and blowers can be found in AMCA Standard 99-1401-66-91, “Classifications for Spark-Resistant Construction.”

A.6.5.5.4 See NFPA 77, *Recommended Practice on Static Electricity*.

A.6.5.5.5 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, *Guide for Venting of Deflagrations*. Dust collectors, when provided by a manufacturer, seldom have properly sized venting to handle a combustible magnesium dust explosion.

A.6.6.1.2 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 pressure of 1380 kPag (200 psig). 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 ant flashback valves.

A.6.6.1.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.6.6.1.2.4 Improper use of vacuum cleaners for magnesium powder accumulations can result in fire or explosion. For in-

formation on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.7.1 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.6.7.1.3 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.6.7.1.3.4.2(2) See NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*, for wall construction details.

A.6.7.2.3 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.6.7.2.7 Sprinkler systems are of vital importance in heavy magnesium casting areas that also contain significant amounts of ordinary combustibles, as sprinkler operation can prevent the magnesium from becoming involved in the fire.

A.6.7.3.5 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.6.7.5.4 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.6.7.5.5 For design information, see NFPA 68, *Guide for Venting of Deflagrations*.

A.6.7.6.6 See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A.6.7.6.8 The safest manner of storage is achieved using no stacking.

A.6.7.7.1 Since 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.6.7.7.4 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.6.8.1.2 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.6.8.1.3 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.6.8.1.6 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A.6.8.1.8 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.6.8.1.13 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.6.8.2 Magnesium is a flammable solid that, once ignited, is best extinguished by smothering (that is, by excluding oxygen). Burning magnesium responds poorly to several types of extinguishing agents used for other types of materials. Use of inappropriate agents can result in accelerating the fire or in causing an explosion (due to hydrogen).

A.6.8.2.2 Automatic sprinkler protection should not be used in areas of buildings where fine magnesium powders or dusts are present, such as blending operations areas. Automatic sprinkler protection should not be used in areas where molten metal can be present.

A.6.8.3.1 The following agents should not be used as extinguishing agents on a magnesium fire because of adverse reaction:

- (1) Water
- (2) Foams
- (3) Halon
- (4) Carbon dioxide
- (5) Sand and other high SiO₂-containing materials

A.6.8.3.2 Application of wet extinguishing agents accelerates a magnesium fire and could result in an explosion.

A.6.8.3.4.1 Water-based extinguishers approved for use on Class A fires should be used only on fires involving ordinary combustibles. Extinguishers approved for Class B fires should be used for fires involving oil, grease, and most flammable liquids. Extinguishers approved for Class C fires should be used for fires involving electrical equipment.

A.6.8.3.5 Experience has shown that dry sodium chloride is one of the most effective chemicals for containing zirconium sponge or fines fires. 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 also are effective. Covering the fire completely reduces the accessible oxygen supply, thereby slowing the burning rate so that eventual extinguishment is achieved.

A.6.8.3.7 Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

A.7.1.1.5 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.7.1.1.14 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.7.1.2 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 of 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. (Also refer to Annex B for additional information.)

A.7.1.3.2 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.7.1.4.2 The design of deflagration venting should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*.

A.7.1.4.2.1 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 assured 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 (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, *Guide for Venting of Deflagrations*.

Deflagration vent closures should be designed such that, once opened, they will remain open to prevent failure from the vacuum following the pressure wave.

A.7.1.4.2.2 For further information on restraining vent closures, see NFPA 68, *Guide for Venting of Deflagrations*.

A.7.1.4.3 High-momentum discharges from relief valves within buildings can disturb dust layers, creating combustible clouds of dust.

A.7.2.1 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 either 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. Investigations of the titanium 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 will liberate 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 can result in an explosive mixture of hydrogen/oxygen. This explosive mixture can be ignited by the residual heat in the melting crucible.

The sequence of the events above 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 tantalum melting furnace that uses water-cooled copper crucibles.

A.7.2.1.1 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.7.2.1.3 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.7.2.1.5 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} 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 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.7.2.1.6 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 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.7.2.1.7.2 Sudden rises in pressure are an indication of the onset of a steam or hydrogen/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.7.2.1.8 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.7.2.2.1.1 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 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.7.2.2.2.2 The collection of moisture in the mold could cause the tantalum to react, causing a fire or explosion.

A.7.2.2.4 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, and they should consider the issue of remote location of control consoles for any new, or modification of, a tantalum melting furnace.

A.7.2.2.5.1 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, by nature, are extremely fine, on the order of submicron, and, hence, will 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 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.7.3 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. Inlets and outlets should be blocked by the suppressant as well as flooding the vessel with it.

Inerting is the preferred approach for protecting against fire and explosion, as it does not allow the 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 shutdown 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.7.3.1.3.1 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 considered for their susceptibility for ignition in a mill operations environment.

A.7.3.1.5 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.7.3.1.6 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 at any time the metal heats up to

high temperatures in a mill environment in excess of the flash point of the lubricants.

A.7.3.1.9 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.7.3.2 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, is typically used for performing tantalum welding operations. Such equipment is often equipped with a mechanical vacuum pump system with inert gas backfilling and purging system to effect evacuation of the chamber and providing 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.7.4.1.2 The quantity of tantalum 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.7.4.2 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 into 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.7.4.2.1 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 this temperature, even passivated tantalum powders 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.7.4.2.4.8 Dryer control systems are critical components providing 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.7.4.2.4.10 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 con-

figuration, 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.7.4.3.5 Refer to discussion under section A.7.4.2.1

A.7.4.4.3 Refer to NFPA 77, *Recommended Practice on Static Electricity*.

A.7.4.5.1 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 the American Institute of Chemical Engineers' Center for Chemical Process Safety Book, "Guidelines for Hazard Evaluation Procedures," 2nd edition, with Worked Examples.

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, it 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, these should pass through close-fitting shaft holes in walls or partitions.

A.7.4.5.2(2) Where deflagration venting is used, its design should be based on information contained in NFPA 68, *Guide for Venting of Deflagrations*. 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.7.4.5.2(5) This method is limited in effectiveness due to the high concentrations of inert material required and the potential for separation during handling. Other methods are preferred.

A.7.4.6 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.7.4.8.1 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 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 a minimum ignition energy of 100 mJ or less.

A.7.4.8.4 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 tantalum powders. The intent of the requirement is to prevent people 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.7.5.1.1 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.7.5.1.2 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) as ground connections tend to corrode and become brittle and break.

A.7.5.1.4 Static-dissipating 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-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 electrical 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 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.7.4.8.1 for additional discussion on antistatic footwear.)

A.7.5.1.5 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.7.5.1.6 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 incandive (and energetic) sparks that are white hot.

A.7.5.3.1 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 a tantalum dust cloud. A hazard 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.7.5.4.1 See the discussion under A.7.4.2.1.

A.7.6.3 See A.7.5.3.1.

A.7.6.5 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 comprising 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. Since 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, there exists a risk of ignition and fire. 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.7.6.5.1 Tantalum compacts after furnacing might also require passivation.

A.7.7.1.2 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.7.7.2.4 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.7.7.2.6 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.7.7.3.2 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, *Guide for Venting of Deflagrations*. 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 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.

A.7.7.3.3 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.7.7.3.6 See Figure A.4.3.4.4(a), Figure A.4.3.4.4(b), Figure A.4.3.4.4(c), and Figure A.7.7.3.6 for the major components of a typical liquid precipitator.

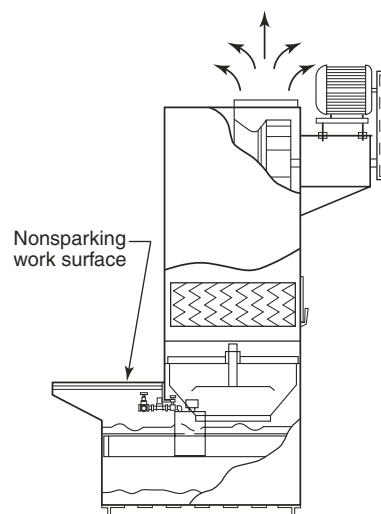


FIGURE A.7.7.3.6 Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

A.7.7.4 Dry dust collectors are not recommended for the collection of tantalum.

A.7.7.4.6 All equipment should be bonded and grounded in accordance with NFPA 77, *Recommended Practice on Static Electricity*.

A.7.8.1.3 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, *Guide for Venting of Deflagrations*. Dust collectors, when provided by a manufacturer, 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 of 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 performing finishing procedures on these types of parts.

A.7.8.2.3 If inert gas is used, the inert gas is to be argon or helium. Nitrogen gas should not be used.

A.7.8.3.3 For information on spacing and sizing of ductwork deflagration vents, see NFPA 68, *Guide for Venting of Deflagrations*.

A.7.8.3.3.2 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, are not subject to NFPA 68, *Guide for Venting of Deflagrations*.

A.7.9.3.1 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.7.10.1.1.1 See NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.7.10.1.4.2 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 explosion, or fire. 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 dusts and fines accumulations with appropriate cleaning equipment.
- (4) Where large quantities of dusts and fines are liberated at frequent intervals, dust-collection systems are to be used.
- (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.7.10.1.4.3 Consideration should be given to the selection of tools when cleaning. Natural bristle brushes have low static electricity accumulation as compared to synthetic bristle brushes. Tools need to be of nonsparking material, such as phosphorous bronze.

A.7.10.1.4.5 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 spark-

ing. 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 bag-house should be protected by an alarm system. This 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, *Guide for Venting of Deflagrations*.

Sparkling, friction, and impact should be minimized in the vacuum system design. The system should be designed by personnel 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.7.10.2.2 Sprinkler systems in buildings or portions of buildings where tantalum is produced or stored pose a serious risk for secondary explosion. When water is applied to burning tantalum powder, hydrogen gas is generated. When confined in an enclosed space, dangerous levels of hydrogen gas can collect and result in the potential for a hydrogen explosion.

A.7.10.3 Experience has shown that sodium chloride is one of the most effective chemicals for containing fires involving tantalum powder. Fire-fighting salts should be checked on a regular basis (such as weekly or monthly) to ensure they have not absorbed moisture (usually evidenced by caking). If damp salt is applied to a tantalum fire, the intense heat will flash the moisture to steam in an explosive manner. Various commercial fire extinguishers are also available with agents approved for combustible metal fires. When using any approved agent, it is important to completely cover the burning material, thus reducing the oxygen supply and slowing the burn rate until the fire is extinguished. If the agent is removed from the burning material too early, re-ignition can occur.

A.7.10.3.1 Dry sodium chloride or other dry chemical compounds suitable for extinguishing or containment of tantalum fires shall be permitted to be substituted for class D fire extinguishers.

- (1) These alternative agents shall be stored in a manner that ensures the agents' effectiveness.
- (2) Shovels or scoops are to be kept readily available adjacent to the container.

A.7.10.5.1 Where employees are expected to conduct any type of fire-fighting operations, the employees should receive training on a regular basis. Additional eye protection should be considered for personnel expected to fight a tantalum fire to protect against the higher degree of emitted light from the burning tantalum.

A.8.1.1.2 NFPA 68, *Guide for Venting of Deflagrations*, contains information on the subject of explosion venting.

A.8.1.1.4 Floors should be slightly crowned to prevent accumulation of water in the vicinity of reduction furnaces.

A.8.1.2.4 For information on emergency gas shutoff valves, see NFPA 54, *National Fuel Gas Code*.

A.8.1.3.2 For information on guidelines for handling and storing chlorine, see *The Chlorine Manual*.

A.8.1.3.3 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 contacted by 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.8.1.4.3 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- or 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. Since 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 bag-house 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 shaking bags. Explosion vents are usually built into the system, as described in NFPA 68, *Guide for Venting of Deflagrations*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.8.1.4.4 Information on spark-resistant fans and blowers can be found in AMCA 99-1401-66-91, "Classifications for Spark-Resistant Construction."

A.8.1.5 Molten titanium and molten titanium chloride present an extremely dangerous fire and fume hazard, in ad-

dition to an explosion hazard, if in contact with water or residual moisture.

A.8.2.1 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- 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 (sodium-potassium alloy) 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.8.2.1.3 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.8.2.2 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 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.8.2.2.1 Titanium ingots contain internal stresses that can cause them to shatter, even up to several days after being wetted.

A.8.2.2.5 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 pyrophoric residue has been removed. These residues might be combustible or pyrophoric, and caution should be exercised.

A.8.3.1 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, or finely divided metal particles, is produced by all sawing and grinding operations.

A.8.3.2.2 See NFPA 77, *Recommended Practice on Static Electricity*.

A.8.4.2.1 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.8.4.2.2 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.8.4.4.1.2 Figure A.7.7.3.6, Figure A.8.4.4.1.2(a), Figure A.8.4.4.1.2(b), Figure A.4.3.4.4(a), and Figure A.4.3.4.4(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.

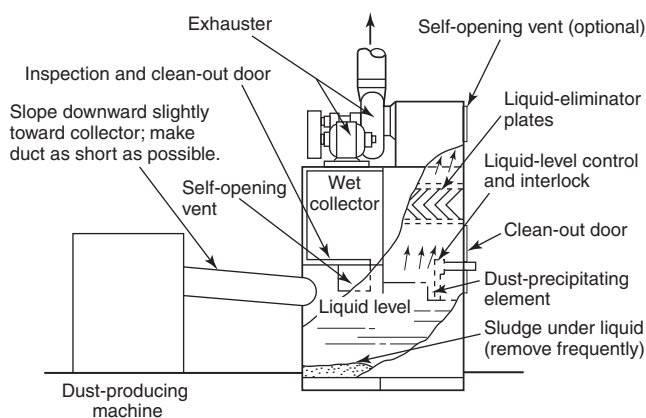


FIGURE A.8.4.4.1.2(a) Typical Liquid Precipitation Collector for Fixed Dust-Producing Equipment.

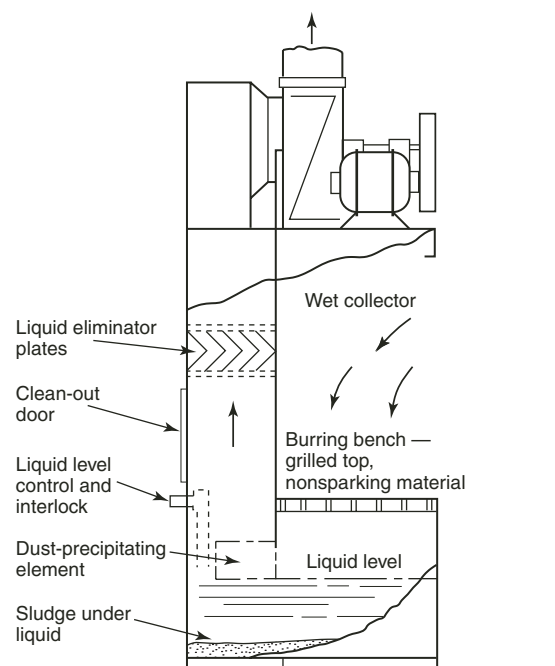


FIGURE A.8.4.4.1.2(b) Typical Liquid Precipitation Collector for Portable Dust-Producing Equipment.

A.8.4.4.4 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 (that is, 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.8.4.5.2 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.

A.8.4.6.4 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.8.4.6.6 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.8.4.7.2 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.8.4.8.7 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, *Guide for Venting of Deflagrations*. 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 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.

A.8.5.1 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 due 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.

A.8.6.1 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 minimum explosive concentration is 0.045 kg/m³ (0.045 oz/ft³). The maximum pressure produced in explosions in a closed bomb at a concentration of 0.5 kg/m³ (0.5 oz/ft³) ranged from 317 kPa to 558 kPa (46 psi to 81 psi). The average rate of pressure rise in these tests ranged from 1724 kPa/sec to 29,650 kPa/sec (250 psi/sec to 4300 psi/sec); the maximum rate of pressure rise ranged from 3792 kPa/sec to over 68,950 kPa/sec (550 psi/sec to over 10,000 psi/sec). The minimum energy of electrical condenser discharge sparks required for ignition of a dust cloud was 10 mJ; for a dust layer, the minimum value was 8 µJ. 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 NFPA *Fire Protection Guide to Hazardous Materials*.)

A.8.6.1.2 Explosion venting systems should be designed according to NFPA 68, *Guide for Venting of Deflagrations*. Explosion venting drying rooms should be considered.

A.8.6.2.3 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 powders. Design considerations should include the use of deflagration venting, proper dust-collection systems, inerting, or a combination of these 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 — 8 percent oxygen

This data was obtained from U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders."

A.8.7.1.3 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.8.7.1.4 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.8.7.1.14 See NFPA 77, *Recommended Practice on Static Electricity*.

A.8.7.2 The principal intent in fighting titanium fires is isolation and containment, rather than extinguishment. Water and other liquids have proven ineffective in extinguishing titanium sponge fires. Streams of water intensify the fire by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of sponge are involved. The great affinity of high-temperature titanium for oxygen will free a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. Entrapment of water under any burning or hot metal can result in a steam explosion.

A.8.7.2.1 Automatic sprinkler protection is not recommended for buildings that contain blending and melting operations.

A.8.7.2.3 Water-based extinguishers suitable for use on Class A fires should be used only on fires in ordinary combustibles. Extinguishers suitable for Class B fires are recommended for fires in oil, grease, and most flammable liquids. Extinguishers suitable for Class C fires should be used for fires in electrical equipment.

A.8.7.2.4 Experience has shown that dry sodium chloride is one of the most effective chemicals for containing fires involving titanium sponge or fines. Fire-fighting salts should be checked periodically to ensure that they have not become caked from moisture. Another effective chemical is a non-metallic 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.8.7.2.6.1 Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

A.8.7.2.8.3 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 titanium powder and titanium fires. In the interest of their own safety, they should be directed by the plant's safety officer or fire-fighting officer.

A.9.1.2.2 NFPA 68, *Guide for Venting of Deflagrations*, contains information on the subject of deflagration venting.

A.9.1.2.4 Floors should be slightly crowned or drained to prevent the accumulation of water in the vicinity of reduction furnaces.

A.9.1.3.4 For additional information on ovens and furnaces, see NFPA 86, *Standard for Ovens and Furnaces*.

A.9.1.4.1 For information on guidelines for handling and storing chlorine, see *The Chlorine Manual*.

A.9.1.4.3 Zirconium 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, 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.9.1.5.4 A high-efficiency cyclone-type collector presents less hazard than a bag-type or media-type collector and, except where collecting 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 there are some instances in which 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. Since this practice presents a strong explosion poten-

tial, 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 shaking bags. Deflagration vents usually are built into the system, in accordance with NFPA 68, *Guide for Venting of Deflagrations*. Care should be exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.9.1.5.5 Information on spark-resistant fans and blowers can be found in AMCA Standard 99-1401-66-91, "Classifications for Spark-Resistant Construction."

A.9.1.6 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.9.1.7.2 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.9.2 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 NaK (sodium-potassium alloy)-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.9.2.1.3 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 relieve safely only much slower increases in pressure, such as might occur from small incursions of water onto the top of the molten metal. Following a breach 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.9.2.1.4 The use of a magnetic field to deflect the electric arc away from the crucible wall should be considered.

A.9.2.2 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. Due to the high power levels used, seams in the crucible should not be exposed to the electric arc or the molten metal.

A.9.2.2.5 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.9.3 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 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 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, or finely divided metal particles, is produced by all sawing and grinding operations.

A.9.3.1.2 See NFPA 77, *Recommended Practice on Static Electricity*, in operations where static electricity presents a hazard.

A.9.4.1.1 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.9.4.2.2 Cleaning methodologies should consider the hazards of creating airborne dusts and the dangers associated with the use of vacuum cleaners.

A.9.4.3.1.2 See Figure A.4.3.4.4(a), Figure A.4.3.4.4(c), Figure A.7.7.3.6, Figure A.8.4.4.1.2(a), and Figure A.8.4.4.1.2(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.9.4.3.4 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.9.4.3.7 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.9.5 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.

A.9.6 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.4.3.4.4(a), Figure A.4.3.4.4(b), Figure A.4.3.4.4(c), and Figure A.8.4.4.1.2(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 minimum explosive concentration is 45.1 g/m³ (0.045 oz/ft³). The maximum pressure produced in explosions in a closed bomb at a concentration of 500 g/m³ (0.5 oz/ft³) ranged from 317 kPa to 558 kPa (46 psi to 81 psi). The average rate of 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. For a dust layer, the minimum value was 8 μ J. 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.9.6.1.1 Experience has shown that the tendency for auto-ignition increases with decreasing particle size of the powder. In particular, in the range of 40 μ and below, the particles exhibit pyrophoric tendencies. This tendency is exacerbated in the presence of moisture.

A.9.6.1.2 For information on designing deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.9.6.2.2 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 powders. 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 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 limiting oxygen concentrations for safe handling of metal powders.)

The test data was 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.9.7.1.3 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention During Welding, Cutting, and Other Hot Work*.

A.9.7.1.4 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.9.7.1.7 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A.9.7.1.9 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.9.7.1.14 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A.9.7.2 The objectives in fighting zirconium fires are isolation and containment, rather than extinguishment. Water and other liquids have proven ineffective in extinguishing zirconium fires. Streams of water intensify the fire by feeding it oxygen. There is also the possibility of causing a steam or hydrogen explosion, particularly if large amounts of zirconium are involved. The great affinity of high-temperature zirconium for oxygen frees a considerable amount of hydrogen, which can reach explosive concentrations in confined spaces. En-

trapment of water under any burning or hot metal can result in a steam explosion.

Because of their unique nature, zirconium fires demand a comprehensive fire protection plan wherever zirconium is processed, handled, used, or stored. This plan should include specific actions in the event of a zirconium fire and should be coordinated with the local facility management, responding fire fighters, and medical personnel.

This plan should recognize the extreme hazards associated with zirconium-water reactions that might occur with sprinkler water. Specific attention should be given to an evacuation plan for personnel in the event of any release of water.

Properly trained personnel who work with zirconium know its hazards. Such personnel are best equipped to extinguish a zirconium fire in its incipient stage. Training should include sufficient information to determine if extinguishment can be accomplished safely and effectively.

A.9.7.2.2 Automatic sprinkler protection should not be used in buildings used for blending and melting.

A.9.7.3.4 Water-based extinguishers approved for use on Class A fires should be used only on fires involving ordinary combustibles. Extinguishers approved for Class B fires should be used for fires involving oil, grease, and most flammable liquids. Extinguishers approved for Class C fires should be used for fires involving electrical equipment.

A.9.7.3.7 Experience has shown that dry sodium chloride is one of the most effective chemicals for containing zirconium sponge or fines fires. 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 also are effective. Covering the fire completely reduces the accessible oxygen supply, thereby slowing the burning rate so that eventual extinguishment is achieved.

A.9.7.3.9 Keeping the equipment in operation until all burning material is removed can reduce damage to the equipment. Small amounts of burning materials can be handled with a shovel to facilitate removal.

A.10.1.5 See NFPA 68, *Guide for Venting of Deflagrations*.

A.10.1.7.1 For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations*.

A.10.2.1.1 Minimum explosible concentrations 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 minimum explosible concentration in the conveying system, the suspension can exceed the MEC in the collector at the end of the system.

A.10.2.1.2 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.10.2.1.4.1 See Figure A.4.3.2.5.1.

A.10.2.1.5 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, 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 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 collector during operation or when shaking bags. Explosion vents are usually built into the system, as described in NFPA 68, *Guide for Venting of Deflagrations*. Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A.10.2.1.6 See NFPA 68, *Guide for Venting of Deflagrations*, for the method to calculate the length of a fireball issuing from a vented collector.

A.10.2.1.7 For example, iron oxide dusts are known to be incompatible with titanium, aluminum, magnesium, and other metal dusts due to the potential for an exothermic thermite reaction (*see A.3.3.35 for additional information*). 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 (that is, 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.10.2.1.9 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.10.2.1.10 For information on bonding and grounding, see NFPA 77, *Recommended Practice on Static Electricity*.

A.10.2.3 See Figure A.4.2.5(a) and Figure A.4.2.5(b).

A.10.2.3.3 The handling of dry metal powder presents a fire and explosion hazard. The hazard increases as the size of the

metal 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 metal powders. Design considerations should include the use of deflagration venting, proper dust-collection systems, inerting, or a combination of these methods. The inert gas used should be determined by test to be appropriate for the metal powder being handled. Some metal powders can react exothermically in pure carbon dioxide atmospheres and in pure nitrogen atmospheres.

For example, tests have shown that the maximum oxygen concentrations allowed for different inert gases to prevent explosions in titanium dust clouds are as follows:

- (1) Carbon dioxide — 0 percent oxygen
- (2) Nitrogen — 6 percent oxygen
- (3) Argon — 4 percent oxygen
- (4) Helium — 8 percent oxygen

The test data was obtained from U.S. Bureau of Mines, RI 3722, "Inflammability and Explosibility of Metal Powders."

A.10.2.4.1 A visual inspection of the cooling water outlet is highly recommended to determine adequate cooling-water flow.

A.10.2.4.5 Precast solid metal ingots used in remelting might often have internal voids or shrink cavities that can contain water. The introduction of water into molten metal presents a severe risk for a catastrophic explosive reaction.

The explosion that can occur due to the rapid phase transformation of water trapped below molten material takes place over a time span of approximately 10^{-5} s to 10^{-4} s. This time span is faster than a condensed phase detonation.

A.10.2.5.4 Typical margins of safety used for pneumatic dust handling are 25 percent to 50 percent of the MEC. For example, published data indicates 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 metal powder-air suspensions can be held below 25 percent to 50 percent of the MEC in the conveying system, the suspension will necessarily 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.

A.10.2.5.5 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.10.2.5.10 For additional information, see NFPA 77, *Recommended Practice on Static Electricity*.

A.10.2.6.3 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.10.2.6.6 See Figure A.4.3.4.4(a), Figure A.8.4.4.1.2(a), and Figure A.8.4.4.1.2(b).

A.10.2.6.8 Some wet metal sludge has the potential to generate hydrogen gas. Sealed covers have the potential to confine hazardous accumulations of hydrogen within the container.

It should be remembered that wetted dust that is not submerged under a cover of water is highly flammable and very dangerous.