NFPA 480

Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders

1998 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101
An International Codes and Standards Organization

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NFPA 480

Standard for the

Storage, Handling, and Processing of Magnesium Solids and Powders

1998 Edition

This edition of NFPA 480, *Standard for the Storage, Handling, and Processing of Magnesium Solids and Powders*, was prepared by the Technical Committee on Combustible Metals and Metal Dusts and acted on by the National Fire Protection Association, Inc., at its Annual Meeting held May 18–21, 1998, in Cincinnati, OH. It was issued by the Standards Council on July 16, 1998, with an effective date of August 5, 1998, and supersedes all previous edition.

Changes other than editorial are indicated by a vertical rule in the margin of the pages on which they appear. These lines are included as an aid to the user in identifying changes from the previous edition.

This edition of NFPA 480 was approved as an American National Standard on August 6, 1998.

Origin and Development of NFPA 480

This standard was begun in 1946, tentatively adopted in 1950, and adopted by the National Fire Protection Association in May 1951. Revisions were adopted by the Association in 1952, 1954, 1957, 1959, 1961, and 1967. The 1967 edition was reconfirmed in 1974.

The 1974 edition was completely revised in 1980, primarily to comply with the NFPA *Manual of Style.* Minor technical amendments were made at that time. This complete revision of the 1974 edition was acted on by the Association at its 1981 Fall Meeting, and the revision was designated the 1982 edition.

The 1987 edition was a reconfirmation of the 1982 edition. The only changes made were minor editorial improvements and redesignation of the standard as NFPA 480.

For the 1993 edition, the Committee completely revised the standard to update the requirements for safe handling of magnesium solids and powders as well to update the fire and dust explosion prevention measures for both. The Committee incorporated the requirements for safe handling of magnesium powder that were previously found in the 1987 edition of NFPA 651, *Standard for the Manufacture of Aluminum and Magnesium Powder* (retitled *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders* in 1998). The Committee revision also incorporated editorial and style revisions to comply with the NFPA *Manual of Style* and to assist in making the document more usable, adoptable, and enforceable.

The 1998 revision incorporates amendments to the entire document. Key changes have been made to Section 4-2 to consolidate requirements applicable to all dust collectors; to paragraph 7-1.2 to add requirements for vacuum cleaning systems; and to Chapter 9 to incorporate fire prevention concepts and fire protection methods developed for other combustible metals.

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

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

Contents

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Standard for the

Storage, Handling, and Processing of Magnesium Solids and Powders

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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 Appendix A.

Information on referenced publications can be found in Chapter 10 and Appendix D.

Chapter 1 General

1-1 Scope.

1-1.1 This standard shall apply to the storage, handling, and processing of magnesium solids at magnesium foundries, processing plants, and commercial storage facilities.

1-1.2 This standard shall also apply to the storage, handling, processing, and manufacture of magnesium powder.

1-1.3 This standard shall not apply to the primary production of magnesium.

1-1.4* This standard shall not apply to the transportation of magnesium in any form on public highways, waterways, or by air or rail.

1-1.5 The requirements of NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Particulate Solids*, shall not apply to magnesium.

1-2 Purpose. The purpose of this standard is to minimize the occurrence of and resulting damage from fire and explosion hazards in the storage, handling, processing, and manufacture of magnesium solids and powders.

1-3 Equivalent Protection.

1-3.1 Existing plants, equipment, structures, and installations that do not comply strictly with the requirements of this standard shall be considered to be in compliance if it can be shown that an equivalent level of protection has been provided, or that no specific hazard shall be created or continue to exist through noncompliance.

1-3.2 This standard shall not be intended to prevent the use of systems, methods, or devices that provide equivalent protection from fire and explosion. NFPA 69, *Standard on Explosion Prevention Systems*, shall be referenced where considering the use of optional systems.

1-4 Definitions. For the purpose of this standard, the terms below shall be defined as follows.

Approved.* Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction.* The organization, office, or individual responsible for approving equipment, an installation, or a procedure.

Fire-Resistive. Meeting the requirements for Type I or Type II construction, as described in NFPA 220, *Standard on Types of Building Construction*.

Heavy Casting. Castings greater than 25 lb (11.3 kg) with walls of large cross-sectional weights [at least $^1/_4$ in. (6.4 mm)]. Castings less than 25 lb (11.3 kg) are considered light castings.

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.

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 identified standards or has been tested and found suitable for a specified purpose.

Magnesium. Refers to either pure metal or alloys having the generally recognized properties of magnesium marketed under different trade names and designations.

Magnesium Powder. Refers to magnesium metal in the form of a chip, granule, flake, or finely divided particle. Any such magnesium metal that is less than $^1/_8$ in. (3.2 mm) in two dimensions or less than $^1/_{20}$ in. (1.3 mm) in single dimension (e.g., magnesium ribbon) will be considered a powder.

Magnesium Powder Production Plant. Facilities or buildings whose primary product is bulk magnesium powder. Facilities or buildings in which powder is produced incidental to operations will not be considered a powder production plant.

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. (Materials reported as noncombustible, when tested in accordance with ASTM E 136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, shall be considered noncombustible materials.)

Shall. Indicates a mandatory requirement.

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

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, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

Swarf. Finely divided metal particles produced by sawing and cutting operations.

Chapter 2 Location and Construction of Magnesium Powder Production Plants

2-1 Location.

2-1.1 Magnesium powder production plants shall be located on a site large enough so that the buildings in which powder is manufactured shall be at least 300 ft (91.5 m) from public roads and from any occupied structure, such as public buildings, dwellings, and business or manufacturing establishments, other than those buildings that are a part of the magnesium powder production plant.

2-1.2 Different production operations shall be located in separate but not adjoining buildings that are located at least 50 ft (15 m) from each other.

Exception: Two buildings less than 50 ft (15 m) apart shall be permitted if the facing wall of the exposed building shall be capable of resisting a blast pressure of 2.0 psig (13.8 kPa gauge) and shall be nonload-bearing, noncombustible, and without openings.

2-1.3 Separate buildings shall be required where different operations, such as but not limited to atomization, grinding, crushing, screening, blending, or packaging are performed.

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

2-2 Security.

2-2.1 This section shall be applied to new and existing facilities. The intent of this section shall be to restrict access by the general public to those facilities and to establish adequate exit facilities for personnel.

2-2.2 The powder production plant shall be surrounded by strong fencing at least 6 ft (1.8 m) high with suitable entrance gates, or otherwise shall be rendered inaccessible.

2-2.3 Security measures taken shall be in accordance with NFPA *101*®, *Life Safety Code*®.

2-3 Building Construction.

2-3.1 All buildings used for the manufacture, packing, or loading for shipment of magnesium powders shall be single story, without basements, constructed of noncombustible materials throughout, and shall have nonload-bearing walls. The buildings shall be designed so that all internal surfaces are readily accessible to facilitate cleaning.

Exception: Other construction types shall be permitted if equivalent protection can be demonstrated.

2-3.2 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.

2-3.3 Floors shall be noncombustible hard surface and non-slip, installed with a minimum number of joints in which powder can collect. The requirements of this subsection shall also apply to elevated platforms, balconies, floors, or gratings. *(See Appendix B.)*

2-3.4 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.

2-3.5 Roof decks shall be watertight.

2-4 Doors and Windows.

2-4.1 All exits shall conform with NFPA *101*, *Life Safety Code*.

2-4.2 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*.

2-4.3* Windows shall be held in place by friction latches and installed so that they open outward.

2-5* Grounding of Equipment. All process equipment and all building steel shall be securely grounded by permanent ground wires to prevent accumulation of static electricity.

2-6 Electrical Power.

2-6.1 All electrical equipment and wiring shall be installed in accordance with NFPA 70, *National Electrical Code*®.

2-6.2* All parts of manufacturing buildings shall be classified.

2-6.3 Buildings shall be provided with emergency lighting systems in accordance with NFPA *101*, *Life Safety Code*. The emergency lighting shall be energized automatically upon loss of electrical power to the buildings.

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

Chapter 3 Magnesium Mill and Foundry Operations

3-1* Melting and Casting Operations.

3-1.1 Buildings used for the melting and casting of magnesium shall be noncombustible. Melt rooms shall provide access to facilitate fire control. Floors shall be of noncombustible construction and be kept clean and free of moisture and standing water.

3-1.2* All solid metal shall be thoroughly dried by preheating and shall be at a temperature not less than 250°F (121°C) throughout when coming into contact with molten magnesium.

3-1.3 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.

3-1.4* Prevention of Molten Magnesium Contact with Foreign Materials.

3-1.4.1 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.

3-1.4.2 Crucible interiors and covers shall be maintained free of iron oxide scale, which could fall into the molten metal.

3-1.4.3 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.

3-1.4.4 Melting pots and crucibles shall be inspected regularly. 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.

3-1.5 Ladles, skimmers, and sludge pans shall be thoroughly dried and preheated before contacting molten metal.

3-1.6 Extreme care shall be exercised in pouring magnesium castings to avoid spillage. All molds shall be thoroughly preheated before pouring.

3-1.7 Operators in melting and casting areas shall wear flame-resistant clothing, high foundry shoes, and face protection. Clothing worn where molten magnesium is present shall have no exposed pockets or cuffs that could trap and retain magnesium.

3-2* Heat Treating.

3-2.1 A standard procedure for checking the uniformity of temperatures at various points within heat-treating furnaces shall be established. Furnaces shall be checked prior to use and at regular intervals during use to identify undesirable hot spots.

3-2.2* Gas- or oil-fired furnaces shall be provided with combustion safety controls.

3-2.3 All furnaces shall have two sets of temperature controls operating independently. One shall maintain the desired operating temperature; the other, 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.

3-2.4 Magnesium parts to be put in a heat-treating furnace shall be free of magnesium turnings, chips, and swarf.

3-2.5 Combustible spacers on pallets shall not be used in a heat-treating furnace.

3-2.6* Aluminum parts, sheets, or separators shall not be included in a furnace load of magnesium.

3-2.7 There shall be strict adherence to the heat-treating temperature cycle recommended by the alloy manufacturer.

3-2.8* Molten salt baths containing nitrates or nitrites shall not be used for heat-treating magnesium alloys.

3-2.9* 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.

3-2.10* Furnaces used to heat magnesium or magnesium alloys shall be inspected and cleaned as necessary to remove any accumulation of loose iron oxide scale.

Chapter 4 Machining, Finishing, and Fabrication of Magnesium

4-1* Machining.

4-1.1 Cutting tools shall not be allowed to ride on the metal without cutting, as frictional heat can ignite any fine metal that is scraped off. For the same reason, the tool shall be backed off as soon as the cut is finished. Cutting tools shall be kept sharp and ground with sufficient rake clearance to minimize rubbing on the end and sides of the tool.

4-1.2* When drilling deep holes (depth greater than 5 times drill diameter) in magnesium, high-helix drills (45 degrees) shall be used to prevent packing of the chips produced.

4-1.3 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. Side relief shall be 5 degrees; end relief shall be from 10 degrees to 20 degrees.

4-1.4 If lubrication is needed, as in tapping or extremely fine grooving, a high–flash point mineral oil shall be used. 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.

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

4-1.5 Where compressed air is used as a coolant, special precautions shall be taken to keep the air dry.

4-1.6 All machines shall be provided with a pan or tray to catch chips or turnings. The pan or tray shall be installed so that it can be readily withdrawn from the machine in case of fire. It shall be readily accessible for chip removal and for application of extinguishing agent to control a fire.

4-1.6.1 During magnesium machining operations, chips shall be removed from the point of generation by continuous or batch removal. Accumulation at the point of generation shall not exceed 3 lb (1.4 kg) dry weight. All chips shall be stored in covered noncombustible containers and removed to a storage area in accordance with Chapter 8.

4-1.6.2 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.

4-2 Dust Collection.

4-2.1 Dust shall be collected by means of suitable hoods or enclosures at each operation. Hoods and enclosures shall be connected either to a wet-type collector or to a cyclone collector and blower located outdoors.

4-2.2 The dust collection system shall be designed and installed so that the dust is collected upstream of the fan.

4-2.3 The use of dry media-type collectors shall be prohibited.

4-2.4 Wet-Type Dust Collectors.

4-2.4.1* 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.

4-2.4.2* Wet-type dust collectors shall be restricted to a dust-loading of no more than 5 grains/ ft^3 (175 grains/m^3) of inlet air on standard configuration collectors.

4-2.4.3 Wet-type dust collectors shall be designed so that the hydrogen being generated from the magnesium contacting the water shall be vented at all times.

4-2.4.4 Means of venting to avoid accumulation of hydrogen shall be maintained. Each chamber of the collector shall be vented to dissipate the hydrogen.

4-2.4.5 Sludge level build-up in the sludge tank of the wet-type dust collector shall not exceed 5 percent of the tank water capacity as measured by volume. Sludge shall be removed from the collector whenever the collector is to remain inoperative for a period of 24 hours or more.

4-2.4.6 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. The auxiliary fan volume shall not be less than 10 percent of the exhaust fan volume.

4-2.4.7 Down-draft bench configuration separators shall maintain no less than 300 ft/min (90 m/min) average work-surface capture velocity at each work station. Work-surface capture velocity shall be determined as a function of nominal work surface area.

4-2.4.8* Each wet-type dust collector shall be dedicated to the collection of magnesium or magnesium alloy only.

4-2.5 Cyclone Dust Collectors.

4-2.5.1 Hoods and enclosures shall be connected to a high-efficiency cyclone(s) and blower located outdoors.

4-2.5.2 The cyclone exhaust shall terminate in a safe, outdoor location. Recycling of air from any dust collector into buildings shall be prohibited.

4-2.5.3 All components of a dust collection system shall be made of conductive materials and shall be watertight.

4-2.5.4 The minimum length of duct from the dust-producing operation(s) to the cyclone shall be 15 ft (4.6 m).

4-2.5.5* Explosion venting shall be permitted to be installed on dry-type dust collection systems.

4-2.6 Ductwork.

4-2.6.1 The discharge duct for wet-type dust collection equipment shall terminate at a safe, outdoor location. Recycling of air from any dust collector into buildings shall be prohibited.

4-2.6.2 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). In systems that involve multiple machines connected to one dust collector, the concentration limit and velocity requirement shall be met throughout the entire system.

4-2.6.3 All components of the dust collection system shall be of conductive material. Connecting ducts or suction tubes between points of collection and separators shall be completely bonded and grounded. Ducts and tubes shall be as short as possible, with no unnecessary bends. Ducts shall be fabricated and installed in accordance with NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials.* Ducts shall have no unused capped connections to the main trunk line where magnesium dust can accumulate.

4-2.6.4 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. A time-delay switch or equivalent device shall be provided on the dust-producing equipment to prevent starting of its motor drive until the separator is in complete operation.

4-3 Cleaning.

4-3.1 Systematic cleaning of the entire grinding area, including roof members, pipes, conduits, et cetera, shall be carried out daily or as often as conditions warrant.

4-3.2 Cleaning shall be done using soft brushes and conductive nonsparking scoops and containers.

4-3.3* Vacuum cleaners shall not be used unless they are specifically listed for use with magnesium powder or dusts.

4-4 Electrical Equipment.

4-4.1* All areas containing dust-producing machines including areas containing dust collection equipment shall be classified in accordance with Article 500 of NFPA 70, *National Electrical Code.*

4-4.2 All electrical equipment shall be inspected and cleaned periodically.

4-4.3 Where flashlights or storage battery–operated lanterns are used, they shall be listed for classified locations.

4-5* Grounding of Equipment. All equipment shall be securely grounded by permanent ground wires to prevent accumulation of static electricity.

4-6 Safety Precautions.

4-6.1 Operator clothing shall be flame-retardant, easily removable, and kept clean and dust-free. Clothing shall be smooth, allowing dust to be brushed off readily. Clothing shall have no pockets or cuffs. Woolen, silk, or fuzzy outer clothing and shoes with exposed steel parts shall be prohibited.

4-6.2 Machinery and equipment described in Section 5-2 shall not be used for processing other metals until the entire grinder and dust-collecting system are thoroughly cleaned. The grinding wheel or belt shall be replaced prior to work on other metals.

4-6.3* 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. In such areas where this type of work is done, all machinery shall be shut down, and the area shall be thoroughly cleaned to remove all accumulations of magnesium dust. 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. Hotwork operations in facilities covered by this standard shall comply with the requirements of NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

4-6.4* Wheels used for grinding magnesium castings shall be relocated for dressing.

Exception: 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.

4-6.5 Nonsparking tools shall be used when making repairs or adjustments around grinding wheels, hoods, or collector units where magnesium dust is present.

4-6.6 Dust collection equipment shall not have filters or other obstructions that will allow accumulation of magnesium dust.

4-7 Drawing, Spinning, and Stamping.

4-7.1 Reliable means to prevent overheating shall be provided where heating magnesium for drawing or spinning.

4-7.2 Clippings and trimmings shall be collected at frequent intervals and placed in clean, dry steel or other noncombustible containers. Fine particles shall be handled according to the requirements of Chapter 5.

Chapter 5 Magnesium Powder — Machinery and Operations

5-1 General Precautions.

5-1.1 In powder handling or manufacturing buildings and in the operation of dust-conveying systems, every precaution shall be taken to avoid the production of sparks from static electricity, electrical faults, friction, or impact (e.g., iron or steel articles on stones, on each other, or on concrete).

5-1.2 Water leakage within or into any building where it can contact magnesium powder shall be prevented to avoid possible spontaneous heating and hydrogen generation.

5-1.3 Electrical heating of any resistance element or load to a high temperature in an area containing a dust hazard shall be prohibited.

5-1.4* Frictional heating shall be minimized by the use of lubrication, inspection programs, and maintenance programs and techniques recommended by the equipment manufacturer.

5-2 Requirements for Machinery.

5-2.1 All combustible magnesium dust-producing machines and conveyors shall be designed, constructed, and operated so that fugitive dust is minimized.

5-2.2* All machinery shall be bonded and grounded to minimize accumulation of static electric charge. This requirement shall be applicable to stamp mortars, mills, fans, and conveyors in all areas where dust is produced or handled. Static-conductive belts shall be used on belt-driven equipment.

5-2.3* Grounded and bonded bearings, properly sealed against dust, shall be used.

5-2.4 Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

5-2.5 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.

5-3 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.

5-4 Charging and Discharging.

5-4.1 All magnesium powder containers not used for shipping into or out of the plant shall be made of metal.

5-4.2 Where charging magnesium powders to (or discharging from) machines, the containers shall be bonded to the equipment and grounded by a suitable grounding conductor.

5-5 Packaging and Storage. Magnesium powder shall be stored in steel drums or other closed conductive containers. The containers shall be tightly sealed and stored in a dry location until ready for shipment or repacking.

Chapter 6 In-Plant Conveying of Magnesium Powder

6-1 Containers.

6-1.1 Transfer of powders in-plant shall be done in covered conductive containers, as described in Chapter 5. Special attention shall be necessary to ensure the magnesium powder is not exposed to moisture.

6-1.2 Powered industrial trucks shall be selected in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation.*

6-1.3 All wheeled containers, hand trucks, and lift trucks shall be grounded.

6-2 Pneumatic Conveying.

6-2.1 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 Section 4-2 and Appendix B.)*

6-2.2* Inert gas conveying systems shall be permitted, if designed in accordance with Chapter 2 of NFPA 69, *Standard on Explosion Prevention Systems.*

6-2.3 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.

6-2.4 The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

6-2.5* A minimum conveying velocity of 3500 ft/min (1068 m/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.

6-3 Ductwork for Conveying Systems.

6-3.1* Deflagration venting (e.g., rupture diaphragms) shall be provided on ductwork. Deflagration vents shall relieve to a safe location outside of the building.

Exception: 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.

6-3.2* 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 125 psi (862 kPa).

Exception: 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.

6-3.3 Conveyor ducts shall be constructed of conductive material. Nonconductive duct liners shall not be used.

6-3.4* Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge. See 5-2.2.

6-3.5 Where the conveying duct is exposed to weather or moisture, it shall be moisture tight.

6-4 Fan Construction and Arrangement.

6-4.1* 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.

6-4.2 Personnel shall not be permitted within 50 ft (15 m) of the fan while it is operating. No maintenance shall be performed on the fan until it is shut down.

Exception: 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.

6-4.3 Fans shall be located outside of all buildings and located so that entrance of dust from the fan exhaust into any building shall be minimized.

6-4.4 Fans shall be electrically interlocked with dust-producing machinery so that the machines shut down if the fans stop.

6-5 Dust Collectors.

6-5.1 Dry dust collectors shall be located outside, in a safe location, and shall be provided with barriers or other means for protection of personnel.

6-5.2 The area around the collector shall be posted with the following:

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

6-5.3 Ductwork shall comply with the provisions of Section 6-3.

6-5.4* The entire dust collection system, including the dust collector, shall be constructed of conductive material and shall be completely bonded and grounded to minimize accumulation of static electric charge.

6-5.5* Dry dust collectors where an explosion hazard exists shall be provided with deflagration vents. 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. Deflagration vents shall be positioned so that a potential blast shall not be directed toward any combustible or frangible structure.

6-5.6 Where repairs on dry dust collectors are necessary, the collectors shall be emptied and residual accumulations of dust thoroughly removed. *(See Section 5-2.)* Ductwork leading into the collector shall be disconnected and blanked off before repair work shall be permitted to be started.

Chapter 7 Prevention of Fugitive Dust Accumulations

7-1 General.

7-1.1 Dust shall not be permitted to accumulate. Spills shall be removed at once, using conductive, nonsparking scoops and soft brooms or brushes having natural fiber bristles. Compressed-air blowdown shall not be permitted.

7-1.2* Vacuum Cleaning Systems.

7-1.2.1 Vacuum cleaning systems shall be used only for removal of dust accumulations too small, too dispersed, or too inaccessible to be thoroughly removed by hand-brushing.

7-1.2.2* Vacuum cleaning systems shall be effectively bonded and grounded to minimize accumulation of static electric charge.

7-1.2.3 Due to the inherent hazards associated with the use of fixed and portable vacuum cleaning systems for finely divided combustible magnesium dust, special engineering considerations shall be given to the design, installation, maintenance, and use of such systems.

7-1.2.4* Portable vacuum cleaners shall be used only if listed or approved for use with combustible magnesium dust.

7-1.2.5 Vacuum cleaner hose shall be conductive and nozzles or fittings shall be made of conductive, nonsparking material. Assembled components shall be conductive and bonded where necessary. Periodic tests for continuity shall be performed.

7-1.2.6 Combustible magnesium dust picked up by a fixed vacuum cleaning system shall be discharged into a container or collector located outside the building.

7-2 Cleaning Frequency.

7-2.1* Operating personnel and supervisors shall exercise great care to prevent the accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned during daily operations.

7-2.2 Regular periodic cleaning, with all machinery idle and power off, shall be performed as frequently as conditions warrant.

Chapter 8 Storage of Magnesium Solids

8-1* Storage of Pigs, Ingots, and Billets.

8-1.1 The size of piles shall be limited. Minimum aisle widths shall be based on the height of the pile as per 8-1.2.4. The pile height shall not exceed 20 ft (6.1 m).

8-1.2 Yard (Outdoor) Storage.

8-1.2.1 Magnesium ingots shall be carefully piled on firm and generally level areas to prevent tilting or toppling. Storage areas and yard pavements shall be well drained. The storage area shall be kept free of grass, weeds, and accumulations of combustible materials.

8-1.2.2 Combustible flooring or supports shall not be used under piles of ingots.

8-1.2.3 The quantity of magnesium stored in any pile shall be kept to a minimum. In no case shall the amount exceed 100,000 lb (45,400 kg).

Exception: Quantities stored shall be permitted to be increased up to a maximum of 1,000,000 lb (454,000 kg) per pile when the following requirements are met:

a) Provision shall be made for drainage of water away from stored material.

(b) The aisle widths shall be equal to the pile height plus 10 ft (3 m), but no less than 15 ft (4.5 m).

(c) Piles shall not be more than 10 ft wide.

8-1.2.4 Aisle width shall be at least one-half the height of the piles and shall be at least 10 ft (3 m).

8-1.2.5 Readily combustible material shall not be stored within a distance of 25 ft (7.6 m) from any pile of magnesium ingots.

8-1.2.6 An open space, equal to the height of the piles plus 10 ft (3 m), shall be provided between the stored magnesium ingots and adjoining property lines where combustible material or buildings are exposed or where the adjacent occupancy can provide fire exposure to the magnesium.

8-1.3* Indoor Storage.

8-1.3.1 Storage shall be in buildings of noncombustible construction.

8-1.3.2 Floors shall be well drained to prevent accumulations of water in puddles.

8-1.3.3 Supports and pallets used under piles of magnesium ingots shall be noncombustible.

8-1.3.4 The quantity of magnesium ingots stored in any one pile shall be kept to a minimum, but in no case shall the amount exceed 50,000 lb (23,000 kg).

Exception: Quantities stored shall be permitted to be increased up to a maximum of 500,000 lb (226,800 kg) per pile when the following requirements are met:

(a) Piles shall not be more than 10 ft (3 m) wide.

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

8-1.3.5 Aisle widths shall comply with 8-1.2.4.

8-1.3.6 Combustible material shall not be stored within a distance of 25 ft (7.6 m) from any pile of magnesium pigs, ingots, and billets.

8-2 Storage of Heavy Castings.

8-2.1 Buildings used for the storage of heavy magnesium castings shall be of noncombustible construction.

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

8-2.2* Floors shall be of noncombustible construction and shall be well drained to prevent accumulations of water in puddles.

8-2.3 All magnesium castings shall be clean and free of chips or fine particles of magnesium when being stored.

8-2.4 The size of storage piles of heavy magnesium castings, either in cartons or crates or free of any packing material, shall be limited to 1250 ft^3(36 m^3). Aisles shall be maintained to permit inspection and effective use of fire protection equipment.

8-2.5 Aisle width shall be at least one-half the height of the piles and shall be at least 10 ft (3 m).

8-2.6* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or other packing materials are present.

8-3 Storage of Light Castings.

8-3.1 Light magnesium castings shall be stored in noncombustible buildings and shall be segregated from other storage.

Exception: Storage of light castings shall be permitted in buildings of combustible construction if the buildings are fully protected by an automatic sprinkler system. (See 8-3.4.)

8-3.2 Piles of stored light magnesium castings, either in cartons or crates or without packing, shall be limited in size to 1000 ft^3 (28 m^3). Light castings shall be segregated from other combustible materials and kept away from flames or sources of heat capable of causing ignition.

8-3.3 Aisle widths shall be at least one-half the height of the piles and shall be at least 10 ft (3 m).

8-3.4* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

8-4 Storage in Racks or Bins.

8-4.1 Racks shall be permitted to be extended along walls in optional lengths. Aisle spaces in front of racks shall be equal to the height of the racks. All aisle spaces shall be kept clear.

8-4.2 Combustible rubbish, spare crates, and separators shall not be permitted to accumulate within the rack space. 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.

8-5 Storage of Scrap Magnesium.

8-5.1 This section shall apply to the storage of scrap magnesium in the form of solids, chips, turnings, swarf, or other fine particles.

8-5.2 Buildings used for the indoor storage of magnesium scrap shall be of noncombustible construction.

8-5.3 Dry magnesium scraps shall be kept well separated from other combustible materials. 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. 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 becoming wet.

8-5.4* Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container at an outside location. Sources of ignition shall be kept away from the drum vent and top. Containers shall not be stacked.

8-5.5* Storage of dry scrap in quantities greater than 50 ft^3 (1.4 m^3) [which is six 55-gal drums (six 208-L drums)] shall be kept separate from other occupancies by fire-resistive construction without window openings or by an open space of at least 50 ft (15 m). Such buildings shall be well-ventilated to avoid the accumulation of hydrogen in the event that the scrap becomes wet.

8-5.6 Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers pending salvage.

8-5.7 Oily rags, packing materials, and similar combustibles shall be permitted in storage bins or areas that store solid magnesium scrap.

8-5.8 The use of automatic sprinklers in magnesium scrap storage buildings or areas shall be prohibited.

8-5.9 Fire extinguishing agents compatible for the hazards present shall be readily available in magnesium scrap storage areas.

8-6 Storage of Magnesium Powder.

8-6.1 Buildings used to store magnesium powder shall be of noncombustible single-story construction.

8-6.2 The use of automatic sprinklers in magnesium powder storage buildings shall be strictly prohibited.

8-6.3 Magnesium powder shall be kept well separated from other combustible or reactive metals.

8-6.4 Magnesium powder shall be stored in closed steel drums or other closed noncombustible containers. The containers shall be stored in dry locations.

8-6.5 Magnesium powder storage areas shall be kept dry and checked for water leakage.

8-6.6* All areas used for the storage of magnesium powder shall be classified in accordance with Article 500 of NFPA 70, *National Electrical Code.*

8-6.7 Fire extinguishing agents compatible for the hazards present shall be readily available in magnesium powder storage areas.

8-6.8 Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 18 ft (5.5 m). Storage shall be stacked in a manner that ensures stability. Under no circumstances shall containers be permitted to topple over. The safest manner of storage is achieved using no stacking.

8-7 Storage of Other Magnesium Products.

8-7.1* This section 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.

8-7.2 Storage in quantities greater than 50 ft^3 (1.4 m^3) shall be separated from storage of other materials that are either combustible or in combustible containers by aisles with a minimum width equal to the height of the piles of magnesium products.

8-7.3 Magnesium products stored in quantities greater than 1000 ft^3 (28 m^3) shall be separated into piles each not larger than 1000 ft^3 (28 m^3), with the minimum aisle width equal to the height of the piles but in no case less than 8 ft (3 m).

8-7.4* The storage area shall be protected by automatic sprinklers in any of the following situations:

(a) Where storage in quantities greater than 1000 ft^3 (28 m^3) is contained in a building of combustible construction
(b) Where magnesium products are packed in combustible crates or cartons
(c) Where there is other combustible storage within 30 ft (9 m) of the magnesium

Chapter 9 Fire Prevention and Fire Protection

9-1 Fire Prevention. The provisions of Chapter 9 shall apply to all magnesium production processes, handling, and storage operations.

9-1.1 Buildings shall comply with the applicable provisions of NFPA *101*, *Life Safety Code.*

9-1.2* Hotwork permits shall be required in designated areas that contain exposed magnesium chips, powder, or sponge. All hotwork areas that require a permit shall be thoroughly cleaned of magnesium chips, powder, or sponge before hotwork is performed.

9-1.3* All containers used to receive molten magnesium shall be cleaned and dried thoroughly before use.

9-1.4 Good housekeeping practices shall be maintained. Supplies shall be stored in an orderly manner with properly maintained aisles to allow routine inspection and segregation of incompatible materials. Supplies of materials in magnesium processing areas shall be limited to those amounts necessary for normal operation.

9-1.5 Ordinary combustible materials, such as paper, wood, cartons, and packing material, shall not be stored or allowed to accumulate in magnesium processing areas.

Exception: This requirement shall not apply where ordinary combustible materials are necessary for the process and are stored in designated areas.

9-1.6* Periodic cleaning of magnesium chips or powder from buildings and machinery shall be carried out as frequently as conditions warrant. Chips or powder shall be removed to a safe storage or disposal area.

9-1.7 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. Records of these inspections shall be kept.

9-1.8* Ordinary combustible materials shall not be discarded in containers used for the collection of sponge, chips, or powder.

Exception: Floor sweepings from magnesium operations shall be permitted to contain small amounts of ordinary combustible materials.

9-1.9 Areas in which flammable and combustible liquids are used shall be in accordance with the requirements of NFPA 30, *Flammable and Combustible Liquids Code.*

9-1.10 Smoking shall not be permitted in areas where ignitable magnesium chips or powder is present. Such areas shall be posted with "no smoking" signs.

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

9-1.11 All electrical equipment and wiring in magnesium production, processing, handling, and storage facilities shall comply with NFPA 70, *National Electrical Code.*

9-1.12 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.

9-1.13* Processing equipment used in magnesium operations shall be electrically bonded and grounded properly in order to prevent accumulations of static electricity.

9-1.14 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.

9-2* General Fire Protection.

9-2.1 A fire protection plan shall be provided for all areas where magnesium is present.

9-2.2* 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.

Exception: 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.

9-2.3 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.

9-2.4 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.

9-2.5 Fire-Fighting Organization. Any fire-fighting organizations that respond to an emergency shall be trained in the hazards involved in fighting a magnesium fire.

9-3 Extinguishing Agents and Application Techniques.

9-3.1* Only listed or approved Class D extinguishing agents or those tested and shown to be effective for extinguishing magnesium fires shall be permitted. A supply of extinguishing agent for manual application shall be kept within easy reach of personnel while they are working with magnesium. The quantity of extinguishing agent shall be sufficient to contain anticipated fires.

9-3.2* The use of pressurized extinguishing agents shall not be permitted on a magnesium powder or chip fire, unless applied carefully so as not to disturb or spread the magnesium powder. This shall be performed only by trained personnel because of the danger of spreading the burning powder or chips or creating a dust cloud. The bulk dry extinguishing agents shall be provided in areas where chips and powders are produced or used. The bulk dry extinguishing agents shall be kept dry (i.e., free of moisture).

9-3.3 Extinguishing agents intended for manual application shall be kept in identified containers. Container lids shall be secured in place to prevent agent contamination and to keep the agent free of moisture. Where large quantities of agent are expected to be needed, a clean, dry shovel shall be provided with the container. Where small amounts are needed, a hand scoop shall be provided with each container.

9-3.4 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.*

9-3.5* 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*, to be used on other classes of fires in areas where solid magnesium is present. Water-based or CO_2 extinguishers shall not be provided in areas containing magnesium chips or powder.

Exception: CO_2 extinguishers shall be permitted in areas containing magnesium for use on electrical fires. Such CO_2 extinguishers shall be clearly marked "Not for use on magnesium fires."

9-3.6* 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. These alternative agents shall be stored in a manner that ensures the agent's effectiveness. Shovels or scoops shall be kept readily available adjacent to the containers. All extinguishing agent storage areas shall be clearly identified.

9-3.7 Magnesium fines shall be segregated by storage in noncombustible drums.

9-3.8* Where a fire occurs in processing equipment, material feed to the equipment shall be stopped. When feed is stopped, the equipment shall be kept in operation.

Exception: Where continued operation of equipment would cause the spread of fire, it shall be stopped.

Chapter 10 Referenced Publications

10-1 The following documents or portions thereof are referenced within this standard as mandatory requirements and shall be considered part of the requirements of this standard. The edition indicated for each referenced mandatory document is the current edition as of the date of the NFPA issuance of this standard. Some of these mandatory documents might also be referenced in this standard for specific informational purposes and, therefore, are also listed in Appendix D.

10-1.1 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.

NFPA 10, *Standard for Portable Fire Extinguishers,* 1998 edition.

NFPA 13, *Standard for the Installation of Sprinkler Systems,* 1996 edition.

NFPA 30, *Flammable and Combustible Liquids Code,* 1996 edition.

NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes*, 1994 edition.

NFPA 69, *Standard on Explosion Prevention Systems,* 1997 edition.

NFPA 70, *National Electrical Code*®, 1999 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1995 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1995 edition.

NFPA 91, *Standard for Exhaust Systems for Air Conveying of Materials,* 1995 edition.

NFPA *101*®, *Life Safety Code*®, 1997 edition.

NFPA 220, *Standard on Types of Building Construction*, 1995 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Conversions, Maintenance, and Operation*, 1996 edition.

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Particulate Solids*, 1998 edition.

NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders*, 1998 edition.

10-1.2 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*, 1992 edition.

Appendix A Explanatory Material

Appendix A is not a part of the requirements of this NFPA document but is included for informational purposes only. This appendix contains explanatory material, numbered to correspond with the applicable text paragraphs.

A-1-1.4 Transportation Regulations. Regulations for the domestic shipment of dangerous goods (magnesium powder is so classified) are issued by the U.S. Department of Transportation (49 *CFR*, Parts 100-199), which has specific responsibility for promulgating the regulations. These regulations are updated and published yearly by the DOT. International shipments are regulated by the United Nations, International Air Transport Association, International Maritime Organization, and other national agencies. Attention is directed to activity now underway to consolidate the regulations under auspices of the United Nations.

A-1-4 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-1-4 Authority Having Jurisdiction. The phrase "authority having jurisdiction" is used in NFPA documents in a broad manner, since jurisdictions and approval agencies vary, as do their responsibilities. Where public safety is primary, the authority having jurisdiction may be a federal, state, local, or other regional department or individual such as a fire chief; fire marshal; chief of a fire prevention bureau, labor department, or health department; building official; electrical inspector; or others having statutory authority. For insurance purposes, an insurance inspection department, rating bureau, or other insurance company representative may be the authority having jurisdiction. In many circumstances, the property owner or his or her designated agent assumes the role of the authority having jurisdiction; at government installations, the commanding officer or departmental official may be the authority having jurisdiction.

A-1-4 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-2-4.3 See NFPA 68, *Guide for Venting of Deflagrations.*

A-2-5 See NFPA 77, *Recommended Practice on Static Electricity.*

A-2-6.2 See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*.

A-3-1 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-3-1.2 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 250°F (121°C) to ensure the removal of moisture. A higher heating temperature might be necessary if the metal is contaminated with corrosion products, salts, or other foreign materials. Molds or tools that will come into contact with molten magnesium should be similarly preheated.

A-3-1.4 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 SF_6 and other protective atmospheres, the problem of iron scale forming above the melt and reacting if it falls into the melt is a concern. 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-3-2 Heat-treating of magnesium has associated fire risks. To retard ignition of magnesium, mixtures of sulfur dioxide (SO_2), sulfur hexafluoride with carbon dioxide (SF_6/CO_2), helium (He), and argon (Ar) with air is recommended in heat-treating furnaces operating above 750°F (399°C).

A-3-2.2 See NFPA 86, *Standard for Ovens and Furnaces.*

A-3-2.6 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. Having magnesium in physical contact with aluminum at an elevated temperature can produce the same effect.

A-3-2.8 Heating magnesium in the presence of oxidizers can result in combustion. Special salt fluxes can be safely used for dip-brazing of magnesium.

A-3-2.9 Magnesium and aluminum form a eutectic alloy with considerably lower melting temperatures and autoignition temperatures than either parent metal.

A-3-2.10 There is a potential for a thermite reaction between magnesium, magnesium alloys, and iron oxide at elevated temperatures.

A-4-1 Flashing of chips during machining should be minimized by any of the following methods:

(a) Keep surface speed below 300 ft/min (1.5 m/sec) or above 2200 ft/min (11 m/sec).
(b) Increase feed rate from 0.0008 in. to 0.010 in. (0.02 mm to 0.25 mm) per revolution.
(c) Control relative humidity in the machining area to 45 percent or lower at 70°F (21°C) room temperature.
(d) Apply a coolant.

A-4-1.2 Use of high-helix drills prevents frictional heat and possible flash fires in fines. High-helix drills are also recommended for drilling deep holes through composite or sandwich sections.

A-4-2.4.1 Interaction between magnesium and aluminum alloy fines (if the aluminum contains more than $^1/_2$ 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 NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders.* See Figures A-4-2.4.1(a), A-4-2.4.1(b), and A-4-2-4.1(c).

A-4-2.4.2 See the table on 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 oz/ft^3 (0.03 g/L) of (air), which is the minimum explosible concentration (MEC).

Minimum explosible concentrations for magnesium dust in air are published in BOM, RI 6516, "Explosibility of Metal Powders." Although the metal dust-air suspension normally can be held below the minimum explosible concentration (MEC) in the conveying system, the suspension can pass through the flammable range in the collector at the end of the system.

A-4-2.4.8 Interaction between magnesium and aluminum alloy fines (if the aluminum contains more than $^1/_2$ 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 NFPA 651, *Standard for the Machining and Finishing of Aluminum and the Production and Handling of Aluminum Powders.*

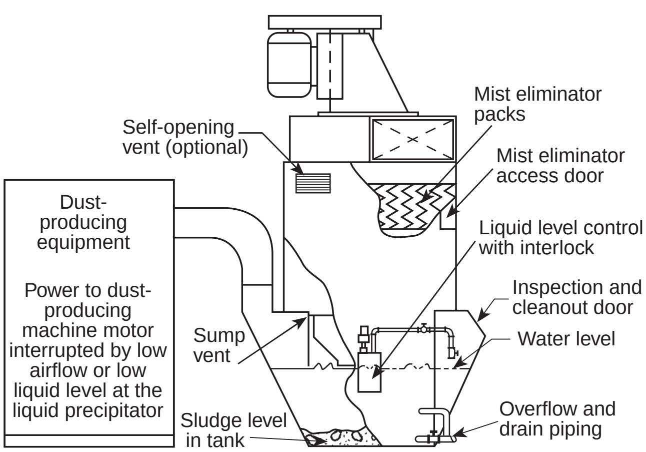

Figure A-4-2.4.1(a) Typical liquid precipitation separator for fixed dust-producing equipment.

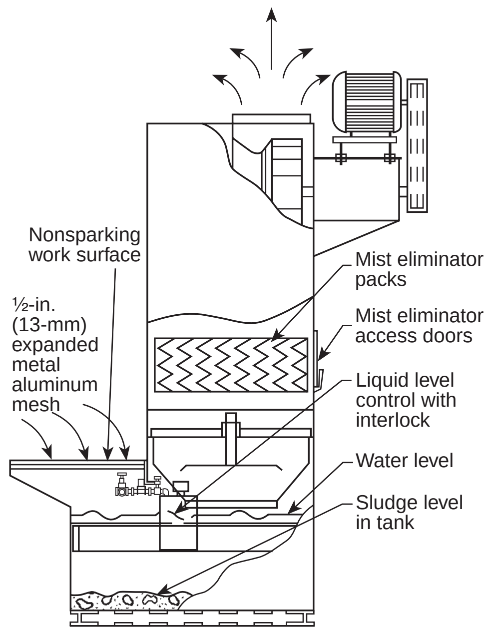

Figure A-4-2.4.1(b) Typical liquid precipitation separator for portable dust-producing equipment.

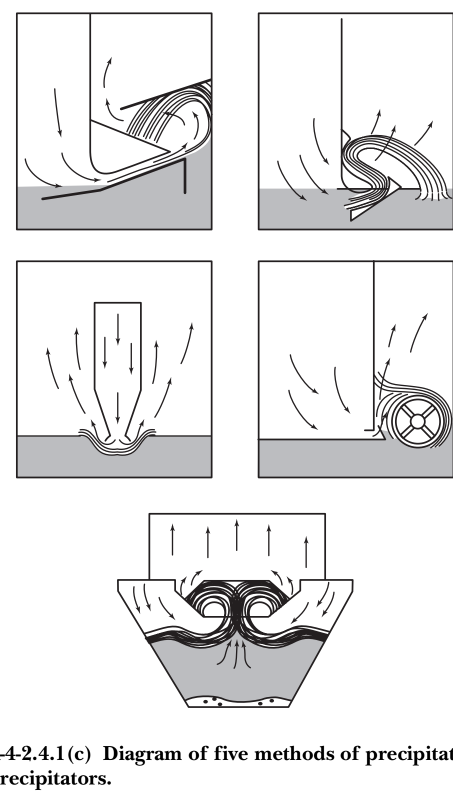

Figure A-4-2.4.1(c) Diagram of five methods of precipitating dust used in precipitators.

A-4-2.5.5 See NFPA 68, *Guide for Venting of Deflagrations*, for guidance on explosion venting.

A-4-3.3 Standard commercial industrial vacuum cleaners should not be used, as they are not safe for use with magnesium.

A-4-4.1 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-4-5 See NFPA 77, *Recommended Practice on Static Electricity.*

A-4-6.3 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-4-6.4 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-5-1.4 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-5-2.2 See NFPA 77, *Recommended Practice on Static Electricity.*

A-5-2.3 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-6-2.2 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-6-2.5 Higher conveying velocities are more desirable and increase safety.

A-6-3.1 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-sec.

A-6-3.2 See NFPA 69, *Standard on Explosion Prevention Systems.*

A-6-3.4 See NFPA 77, *Recommended Practice on Static Electricity.*

A-6-4.1 Information on spark-resistant fans and blowers can be found in AMCA (Air Movement and Control Association) Standard No. 99-0401-91.

A-6-5.4 See NFPA 77, *Recommended Practice on Static Electricity.*

A-6-5.5 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 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-7-1.2 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 50 ft (15 m) away. If the collector is located closer than 50 ft (15 m), 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 200 psig (1380 kPa gauge). 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 anti-flashback valves.

A-7-1.2.2 See NFPA 77, *Recommended Practice on Static Electricity.*

A-7-1.2.4 Improper use of vacuum cleaners for magnesium powder accumulations can result in fire or explosion. For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A-7-2.1 See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A-8-1 Industrial buildings or separate storage areas in which magnesium parts are being stored in quantities greater than 500 lb (227 kg), or where these magnesium parts are the primary hazard, should be labeled in accordance with NFPA 704, *Standard System for the Identification of the Hazards of Materials for Emergency Response.* This serves as a warning to fire fighters on the potential risk in the event of an emergency.

A-8-1.3 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-8-1.3.4(b) See NFPA 221, *Standard for Fire Walls and Fire Barrier Walls*, for wall construction details.

A-8-2.2 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-8-2.6 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-8-3.4 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-8-5.4 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-8-5.5 For design information, see NFPA 68, *Guide for Venting of Deflagrations.*

A-8-6.6 See NFPA 499, *Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

A-8-7.1 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:

(a) Whether or not the magnesium is exposed on the outside of the assembly

(b) How fast or how completely the packaging material might burn away to expose the magnesium

(c) Height and arrangement of the storage array

(d) Intensity of any exposure fire

(e) 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-8-7.4 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-9-1.2 For information on cutting and welding practices, see NFPA 51B, *Standard for Fire Prevention in Use of Cutting and Welding Processes.*

A-9-1.3 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-9-1.6 Consideration should be given to the potential ignition sources associated with the operation of cleaning and processing equipment during the cleaning operation.

A-9-1.8 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-9-1.13 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity*.

A-9-2 Magnesium is a flammable solid that, once ignited, shall be best extinguished by smothering (i.e., 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-9-2.2 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-9-3.1 The following agents should not be used as extinguishing agents on a magnesium fire because of adverse reaction:

(a) Water

(b) Gaseous-based foams

(c) Halon

(d) Carbon dioxide

(e) Sand and other high SiO_2–containing materials

A-9-3.2 Application of wet extinguishing agents accelerates a magnesium fire and could result in an explosion.

A-9-3.5 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-9-3.6 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-9-3.8 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.

Appendix B Supplementary Information on Magnesium

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

B-1 Properties. Magnesium, a silvery white metal with an atomic weight of 24.32 and specific gravity of 1.74, is one of the lightest known structural metals. The melting point of magnesium is 1202°F (650°C). The ignition temperature is generally considered to be close to the melting point, but ignition of magnesium in certain forms can occur at temperatures below the melting point. Magnesium ribbon, fine magnesium shavings, and magnesium powders can be ignited under certain conditions at temperatures of about 950°F (510°C), and a very finely divided magnesium powder has been ignited at temperatures below 900°F (482°C).

Commercially pure magnesium contains traces of aluminum, copper, iron, manganese, nickel, and silicon, but these contaminants in typical analyses generally total less than 0.2 percent. Metal marketed under different trade names and commonly referred to as magnesium might be one of a large number of different alloys containing different percentages of magnesium, aluminum, zinc, and manganese. Some of these alloys can have ignition temperatures considerably lower than that determined for pure magnesium. In some cases, the melting point of certain alloys can be as low as 800°F (427°C) and can ignite if held at this lower temperature for some time.

B-2 Radioactive Alloys. A few magnesium alloys are produced that contain thorium. Thorium, which is a low-level radioactive material, is used in these alloys up to a nominal concentration of 3 percent.

The natural decay or "daughter" products of thorium are locked in the alloy until such time as the metal is melted, burned, or chemically disintegrated. Under fire conditions, these decay products exist within visible fumes and are diluted as the visible fumes dissipate. These elements can be inhaled with possible irradiation of lung tissue and deposition in bone structure. Maximum permissible airborne concentrations of such radioactive materials have been established by the Nuclear Regulatory Commission and are based on continuous exposure for a normal 40-hour work week.

B-3 Spot Tests for Magnesium.

B-3.1 Acetic Acid Test. In the construction or assembly of certain machinery or equipment, magnesium or one of its alloys having similar properties might be used for a few of the component parts, and where finished or painted products are being stored or handled, it can be difficult to determine the percentage of magnesium. Investigation has shown that silver nitrate or acetic acid (vinegar) can be used to distinguish between parts composed of magnesium and those composed of aluminum. The portion of metal to be tested is first cleaned of grease, dirt, oxide, et cetera, using sandpaper or steel wool. After the test area has been prepared, a drop of acetic acid is placed on it. If hydrogen bubbles develop, then the piece being tested is magnesium.

B-3.2 Silver Nitrate Test. The test solution is prepared by dissolving about 5 g of silver nitrate ($AgNO_3$) in 1 L of distilled water. The application of this solution immediately produces a black coloration on magnesium or a magnesium alloy. (This coloration is essentially reduced silver.) No coloration is noted on aluminum and its alloys, or most other metals. Zinc and cadmium exhibit a similar black coloration but are much heavier.

B-4 Combustibility and Explosibility. The ignitibility potential of magnesium depends to a large extent upon the size and shape of the material as well as the size and intensity of the source of ignition. Where magnesium exists in the form of ribbon, shavings, or chips with thin, featherlike edges, or as grinding dust, a spark can be sufficient to start the material burning. Heavier pieces such as ingots and thick wall castings are difficult to ignite because heat is conducted away rapidly from the source of ignition. If the entire piece of metal is raised to the ignition temperature [about 1200°F (649°C) for pure magnesium and many of the alloys], self-sustained burning will occur.

The combustibility of magnesium, the ineffectiveness of ordinary types of extinguishing agents on magnesium fires, and the fact that, under certain conditions, the application of some of these agents intensifies burning and can release hydrogen to form an explosive gas–air mixture, all combine to create serious fire and explosion hazards.

Magnesium, in its solid form, melts as it burns and can form puddles of molten magnesium that, in the presence of sufficient moisture, can pose explosion hazards similar to those associated with other molten metals.

B-5 General.

B-5.1 Electrically conductive flooring is often employed in magnesium powder plants, although it is recognized that it is difficult to maintain the conductivity of the floor over a period of time using currently available materials.

B-5.2 The surface of a conductive floor provides 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.

B-5.3 The maximum resistance of a conductive floor is usually less than 1,000,000 ohms, as measured between two electrodes placed 3 ft (0.3 m) apart at any two points on the floor. The minimum resistance is usually greater than 25,000 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 static electric shocks. Resistance values should be checked at regular intervals.

B-6 Testing for Minimum and Maximum Resistance. The following equipment and procedures are accepted practice.

B-6.1 Each electrode weighs 5 lb (2.2 kg) and has a dry, flat, circular contact area 2.5 in. (63.5 mm) in diameter. The electrode consists of a surface of aluminum foil 0.0005 in. to 0.001 in. (0.013 mm to 0.025 mm) thick, backed by a layer of rubber 0.25 in. (6.4 mm) thick, and measuring 40 to 60 durometer hardness, as determined by a shore-type durometer or equivalent. *(See ASTM D 2240, Standard Test Method for Rubber Property — Durometer Hardness.)*

B-6.2 Resistance should be measured with a suitably calibrated ohmmeter that can operate on a nominal open circuit output voltage of 500 volts dc and a short-circuit current of 2.5 milliamperes to 10 milliamperes.

B-6.3 Measurements should be made at five or more locations in each room and the results averaged.

B-6.4 To comply with the maximum resistance limit, the average of all measurements should be less than 1,000,000 ohms.

B-6.5 To comply with the minimum resistance limit, no individual measurement should be less than 10,000 ohms, and the average of not fewer than five measurements should be greater than 25,000 ohms.

B-6.6 Where resistance to ground is measured, two measurements are customarily made at each location; the test leads are interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 3 ft (0.9 m) from any ground connection or grounded object resting on the floor.

(If resistance changes appreciably over time during a measurement, the value observed after the voltage has been applied for about 5 minutes should be considered the measured value.)

B-7 Building Construction. While noncombustible construction is preferred for buildings occupied by magnesium melting and processing operations, limited-combustible and combustible construction can be permitted in appropriate circumstances.

B-7.1 Moisture and foreign material are dangerous where molten metal is present. Such moisture can result from outdoor storage or from collection of condensate during indoor storage.

B-7.2 Flash fires in fine dust can result in serious injury. While the chance of a flash fire igniting castings is remote, a fire in accumulated dust can be intense enough to cause ignition of castings.

B-7.3 Fire can occur in furnaces or ovens where magnesium is being heat-treated if there is lack of proper temperature control or if the surface of the metal is not free of dust or fine particles of metal. Failure to provide for proper circulation of the heated air in the furnace can result in overheating or higher temperatures in certain zones than those indicated by the thermocouples that operate the temperature control devices.

B-7.3.1 Direct contact between aluminum and magnesium at heat-treating temperatures promotes diffusion and alloying of one metal with the other, resulting in the formation of low-melting, ignitible alloys.

B-7.3.2 Certain commonly used mixtures of molten nitrates and nitrites can react explosively with the magnesium alloys immersed in them.

B-8 Machining magnesium includes sawing, turning, chipping, drilling, routing, reaming, tapping, milling, and shaping. Magnesium can usually be machined at the maximum speeds obtainable on modern machine tools. The low power required allows heavy depths of cut and high rates of feed, which are consistent with good workmanship. The resulting chips are thick and massive; they seldom ignite due to their large heat capacity.

B-9 Magnesium pigs, ingots, and billets are not easily ignited, but they burn if exposed to fire of sufficient intensity.

B-9.1 Heavy castings [25 lb (11.3 kg) or greater] having walls with large cross sections [at least $^1/_4$ in. (6.4 mm)] can be ignited after some delay when in contact with burning magnesium chips or when exposed to fires in ordinary combustible materials.

B-10 Prime (commercially pure) magnesium chips and fines are commonly used in Grignard and other chemical reactions. These chips are generally free of contaminants and are not subject to spontaneous ignition. Where such chips are produced, shipped, and stored for chemical and metallurgical process purposes, the conditions of handling and storage are such that a fire is unlikely.

Although water should not be applied to a large chip fire, automatic sprinklers are valuable in confining or extinguishing an incipient fire in packaging and in small amounts of chips, provided detection and discharge are rapid.

B-11 Although the flame temperature of burning magnesium is about 7200°F (3983°C), the heat of combustion is only about half that of common petroleum products. Thus, fire-fighting personnel can move close to a fire during extinguishment, if care is exercised.

B-11.1 Fires in magnesium should be extinguished using a Class D extinguishing agent or a dry, inert granular material.

B-11.2 Magnesium fires are more easily extinguished if attacked with the proper extinguishing agents during the early stages of the fire. Certain extinguishing agents accelerate a magnesium fire. These agents include foam, carbon dioxide, halogenated agents, and dry chemical agents containing mono- or diammonium phosphate. Also, the use of water on a magnesium chip or powder fire should be avoided. It is very difficult to extinguish a massive fire in magnesium powder. The major problem involves control of fires in the incipient stage.

The fire area should not be re-entered until all combustion has stopped and the material has cooled to ambient temperature.

B-11.3 Reignition can occur due to high localized heat or spontaneous heating. To avoid reignition, the residual material should be immediately smothered.

B-11.4 It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper method of fighting Class D fires.

B-12 Provisions should be made to automatically cut off electrical power and lighting circuits in manufacturing buildings when one or more safety-sensing devices are activated by high pressure, low airflow, abnormal oxygen content, excessive vibration, or other pertinent factors that are being monitored. Alternatively, these sensing devices should be arranged to sound an alarm in those locations where prompt corrective action can be taken.

B-13 Temperature-sensing elements connected to alarms or machine stop switches should be employed for locations where overheating of bearings or other elements might be anticipated.

B-14 Open bin storage is not desirable. Storage bins for powders should be sealed and purged with inert gas prior to filling.

Appendix C Explosibility of Magnesium Dust

This appendix is not a part of the requirements of this NFPA document but is included for informational purposes only.

C-1 Definition.

Deflagration. An explosion in which the rate of propagation of the flame front into the unreacted medium occurs at less than sonic speed. If the shock wave propagates at a rate greater than the speed of sound, it becomes a detonation.

C-2 Explosions in Magnesium–Air Dust Mixtures. Magnesium dust is a potentially hazardous material when suspended in air. The finer the dust particle size, the more easily it disperses, the longer it takes to settle, and the easier it is to ignite.

In order for a magnesium–air dust cloud to experience a deflagration (explosion), the following two conditions are necessary:

(a) An ignitable concentration of dust in air
(b) An ignition source of sufficient strength to ignite the combustible air–dust mixture

Research conducted by the U.S. Bureau of Mines and others over many years has established values for these parameters. In using these data for the design of industrial equipment and systems, it should be kept in mind that other factors such as metal purity, particle size distribution, moisture, ambient pressure and temperature, and turbulence all affect the exact conditions for initiating explosions in such dust clouds.

A summary of the best available information for unalloyed magnesium dust in air is listed in Table C-2. Attention is directed to the fact that the data shown are for 200 mesh (less than 74 microns) in small unvented containers. These conditions are not truly representative of magnesium powder manufacturing but provide useful guidelines for avoiding accidents. For this reason, an additional safety factor should be used where applying this information to industrial-scale operations. A safety factor of 2-3 is suggested.

Table C-2 Explosion Characteristics of Unalloyed Magnesium Dust in Air [200 Mesh (74 microns)]

Explosion Characteristics	Values
Explosibility index[1]	10
Ignition sensitivity[2]	3.0
Explosion severity[3]	7.4
Maximum explosion pressure	115 psig (793 kPa gauge)
Maximum rate of pressure rise	15,000 psi/sec (793 kPa gauge)
Ignition temperature cloud	1040°F(560°C)
Minimum cloud ignition energy	0.04 joules (26.4 watt/sec)
Minimum explosion concentration	0.03 oz/ft^3
Limiting oxygen percent for spark ignition[4]	—

Note: K_{St} values vary for specific particle sizes.
[1]Explosibility Index = ignition sensitivity × explosion severity
[2]Ignition sensitivity =

$$\frac{\text{[Ignition temp.} \times \text{min. energy} \times \text{min. concentration (LEL)]}_{\text{Pittsburgh coal dust}}}{\text{[Ignition temp.} \times \text{min. energy} \times \text{min. concentration]}_{\text{sample dust}}}$$

[3]Explosion Severity =

$$\frac{\text{[Max. explosion} \times \text{max. rate of pressure rise]}_{\text{Pittsburgh Coal Dust}}}{\text{[Max. explosion} \times \text{max. rate of pressure rise]}_{\text{sample dust}}}$$

[4]Burns in carbon dioxide, nitrogen, and halons.

Magnesium dust explosions are characterized by very rapid rates of pressure rise to a maximum pressure of approximately 115 psig (793 kPa gauge). Limited industrial loss experience indicates the use of venting and explosion suppression techniques can be impractical for large-size vessels. As a consequence, the avoidance of conditions that can lead to explosions is of particular importance with fine magnesium powders.

It has been determined that the presence of some coarse particles, greater than 100 mesh (150 microns) in size, in magnesium dust has little effect on the initiation of explosions in such dust clouds. For this reason, the particle size distribution of the powders in air systems should be known, and equipment designs and safe operating procedures should be based on the expected concentration of less than 100 mesh (less than 149 microns) powder in these systems. In the absence of this information, the total amount of powder should be used. While this can limit production rates, it provides an additional factor of safety when dealing with undocumented powders.

From a practical standpoint, a combination of explosion containment with other techniques might be the only other way to avoid personal injury and property damage in manufacturing operations unless oxygen reduction by dilution with argon or helium is employed. This containment technique, together with the avoidance of conditions that can lead to dust explosions, represents the best way of avoiding catastrophic accidents in magnesium dust–handling equipment and systems.

Dust clouds can be ignited by flames, arcs, high-temperature surfaces, and static and friction sparks, et cetera. The destructive effect of magnesium dust explosions can be greater than that of some vapor and gas explosions because of the comparatively high rate at which the pressure rises in some dust explosions. This results in longer impulse-loading on personnel and structures than that resulting from a gas explosion and is the factor that causes a dust explosion to be more destructive. Attention is directed to the fact that a 0.5 psig (3.5 kPa gauge) overpressure will cause an 8-in. (200-mm) concrete block wall to fail. It is obvious that this overpressure is reached extremely rapidly where the rate of pressure rise is 15,000 psi/sec (103,410 kPa/sec) and the maximum pressure reached is 115 psig (793 kPa gauge).

In pneumatic conveying systems, proper selection of fan or blower capacity can be used to maintain a powder concentration below the lower flammability limit (LFL) of 0.03 oz/ft^3(0.03 g/L) shown in Table C-2. If the quantity of powder to be transported is predetermined, the fan can be selected to provide enough conveying air to keep the dust concentration below the ignitible level. Care should be taken, however, to maintain sufficient superficial air velocity [over 3500 ft/min (1068 m/min)] in the duct system to avoid saltation in horizontal lines and drop-out in vertical lines.

While the complete design of a "safe" system is beyond the scope of this appendix, a simplified example serves to illustrate the above point. For instance, to transport 10 lb/min (4.5 kg/min) of fine [less than 100 mesh (less than 149 microns)] magnesium powder introduced uniformly into an air-conveying system while maintaining a dust concentration below the 0.03 oz/ft^3(0.03 g/L) flammability level, the airflow is calculated as follows:

$$\text{Air needed} = \frac{10 \text{lb/min} \times 16 \text{ oz}}{0.03 \text{ oz/ft}^3} = 5333.3 \text{ ft}^3\text{/min}$$

For a 14-in. (356-mm) diameter round duct, the superficial air velocity from the following equation is 4994 ft/min (1524 m/min), neglecting density effects.

$$Q = AV$$

where:
Q = quantity of airflow
A = cross-sectional area
V = velocity
Q = 5333.3/1.068 = 4994 ft/min (1524 m/mi)

NOTE: These calculations do not take into account the effects of temperature, altitude, and humidity on the airflow. The result indicates that to maintain a nonignitible dust concentration, the amount of air needed per pound of powder is quite large. The standard density of dry air is taken at 0.075 lb/ft^3.

$$\left[\frac{(5333.3 \text{ ft}^3\text{/min})}{10 \text{ lb}} \times 0.075 = 40 \text{ lb}\right]$$