ANSI/NFPA 480 An American National Standard August 20, 1993

NFPA 480 Storage, Handling, and Processing of Magnesium Solids and Powders 1993 Edition

National Fire Protection Association, 1 Batterymarch Park, PO Box 9101, Quincy, MA 02269-9101

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There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

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NFPA 480

Standard for the

Storage, Handling, and Processing of Magnesium Solids and Powders

1993 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 24-27, 1993, in Orlando, FL. It was issued by the Standards Council on July 23, 1993, with an effective date of August 20, 1993, and supersedes all previous editions.

The 1993 edition of this document has been approved by the American National Standards Institute.

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 this 1993 edition, the Committee has completely revised the standard to update the requirements for safe handling of magnesium solids and powders as well as updating the fire and dust explosion prevention measures for both. The Committee has 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*. The Committee revision has 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.

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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.

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 Technical 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

NFPA 480

Standard for the

Storage, Handling, and Processing of Magnesium Solids and Powders

1993 Edition

NOTICE: An asterisk (*) following the number or letter designating a paragraph indicates explanatory material on that paragraph 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 Materials*, 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 is not 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."

NOTE: 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 or 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 concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction. The "authority having jurisdiction" is the organization, office or individual responsible for "approving" equipment, an installation or a procedure.

NOTE: 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, 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 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."

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. Heavy castings are greater than 25 lb (11.3 kg) and have walls with large cross section weights [at least $\frac{1}{4}$ in. (6.4 mm)]. Castings less than 25 lb (11.3 kg) shall be considered light castings.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization 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 or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which 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.

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 0.05 in. (1.3 mm) in single dimension (e.g., magnesium ribbon) shall 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 shall 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 E136, *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.

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 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, packaging, or other process 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 to those facilities by the general public 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®*. (*See 5-9.2.3 of NFPA 101.*)

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 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 where dust can be produced, which are not of monolithic construction, 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 nonslip, 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 sq ft (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 have easy and adequate access to facilitate fire control. Floors around melting operations shall be of hard-burned or vitreous paving block, cast-iron plate, or steel plate, laid in concrete and kept clean and free of moisture.

Exception: Melting and casting shall be permitted in buildings of combustible (Type IV) construction if highly acidic or corrosive conditions are present.

3-1.2 All metal added to melting pots shall be thoroughly dried.

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 Furnace settings shall be kept dry and free of iron scale. Safety runoff containers shall be provided for all melting pots and crucibles. Melting pots and crucibles shall be inspected regularly. Pots and crucibles that show evidence of possible failure or that allow molten metal to contact concrete or iron scale shall be 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. Permanent molds shall be thoroughly preheated before pouring. Permanent molds shall also be purged with a mixture of sulfur hexafluoride/air/carbon dioxide (SF_6/air/CO_2), argon (Ar), helium (He), or sulfur dioxide gas (SO_2) prior to use and between pourings.

3-1.7 Operators in melting and casting areas shall wear flame-resistant clothing, high foundry shoes, and adequate face protection.

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 Furnaces shall be properly and tightly constructed. Gas- or oil-fired furnaces shall be provided with combustion safety controls. (*See NFPA 86, Standard for Ovens and Furnaces.*)

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.

Chapter 4 Machining 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 on tools used in grooving and parting operations shall be maintained, 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 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 dry-type dust collector and blower located outdoors or to a wet-type collector.

4-2.2 Where practical, the dust collection system shall be designed and installed so that the dust is collected upstream of blowers.

4-2.3 Wet Dust Collection.

4-2.3.1 Wet-type collectors shall be permitted to be located indoors.

4-2.3.2 The discharge duct for wet dust collection equipment shall terminate at a safe outside location.

4-2.3.3 The ductwork, dust collector, and fan system shall be designed such that the concentration of magnesium dust in the system is less than 25 percent of the lower flammable limit (LFL) of magnesium.

4-2.3.4 All components of the dust collection system shall be of conductive material.

4-2.3.5 Connecting ducts or suction tubes shall be completely grounded and bonded, with no unnecessary bends. Ducts shall be fabricated and assembled, and shall have a smooth interior and internal lap joints pointing in the direction of airflow. Ducts shall have no unused capped side outlets, pockets, or other dead-end spaces that can allow an accumulation of dust.

4-2.3.6 The power supply to dust-producing machines shall be interlocked with the motor driving the exhaust blower and the liquid-level controller of the liquid precipitation separator in such a way that improper functioning of the dust collection system shall shut down the machine it serves. The interlock system shall function under conditions of belt failure. A time-delay switch or equivalent device shall be provided on the dust-producing machine to prevent starting of its motor drive until the liquid precipitation separator is in complete operation and several air changes have swept out any residual hydrogen.

4-2.4 Liquid Precipitation Collectors.

4-2.4.1* Each dust-producing machine shall be dedicated to the collection of magnesium or magnesium alloy only and have its own dust-separating unit. (*See Figure 4-2.4.2.*)

Exception: With multiunit machines, two dust-producing machines shall be permitted to be served by a single separator. Where multiunit machines are in use, only magnesium shall be processed in each unit.

4-2.4.2 Wet collectors shall be restricted to a dust-loading of no more than 5 gr/cu ft (175 gr/m^3) of inlet air on standard configuration collectors. (*See "Industrial Ventilation: A Manual of Recommended Practice" table on Range of Particle Size, Concentration, and Collector Performance.*)

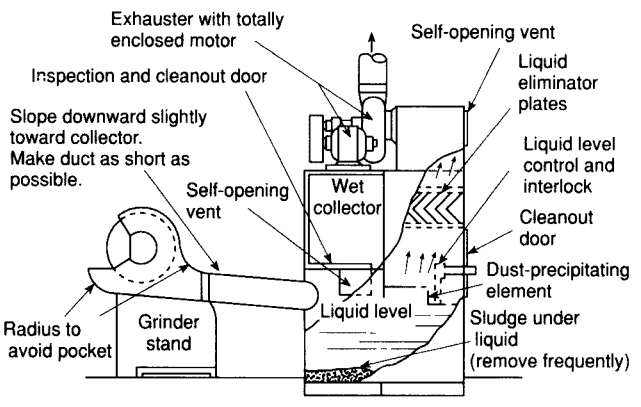

Figure 4-2.4.2 Typical liquid precipitation separation for grinding.

4-2.4.3 Liquid precipitation separators shall be designed such 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 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 Liquid precipitators 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.

4-2.5 Down-Draft Wet Collectors.

4-2.5.1 The number of dust-producing machines shall be limited only by the design of the down-draft bench. All such designed stations shall be individually partitioned from each other. Each down-draft collector shall be used only for the collection of magnesium dust. (*See Figure 4-2.5.1.*)

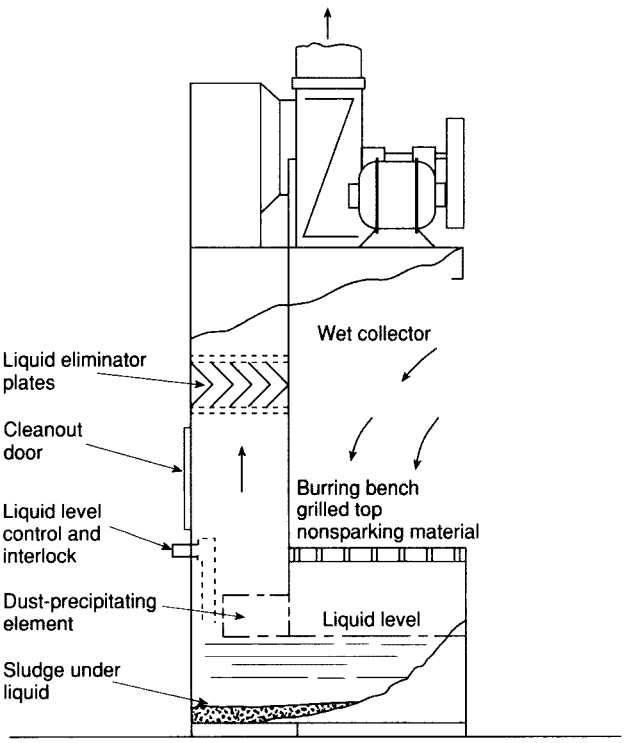

Figure 4-2.5.1 Typical down-draft separator for grinding.

4-2.5.2 The power supply to dust-producing machines shall be interlocked with the motor driving the exhaust blower and the liquid-level controller of the down-draft separator in such a way that improper functioning of the dust collection system will shut down the machine it serves. A time-delay switch or equivalent device shall be provided

on the dust-producing machine to prevent starting of its motor drive until the down-draft separator is in complete operation and several air changes have swept out any residual hydrogen.

4-2.5.3 Wet collectors shall be restricted to a dust-loading of no more than 2 gr/cu ft (70 gr/m^3) of inlet air on down-draft bench configuration separators. (*See "Industrial Ventilation: A Manual of Recommended Practice" table on Range of Particle Size, Concentration, and Collector Performance.*)

4-2.5.4 Down-draft bench configuration separators shall maintain no less than 300 ft/min (1.5 m/sec) average work surface capture velocity at each work station. Work surface capture velocity shall be determined as a function of nominal work surface area.

4-2.5.5 Sludge level build-up in the sludge tank of the wet collector shall not exceed 5 percent of the tank water capacity as measured by volume. Sludge shall be removed from the collectors whenever the collector is to remain inoperative for a period of 24 hours or more.

4-2.5.6 Positive venting of the sludge tank shall be maintained at all times 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.

4-2.5.7 Any chambers that are enclosed shall be vented by natural ventilation.

4-2.6 Dry Dust Collection.

4-2.6.1* Dust shall be collected by means of suitable hoods or enclosures at each operation.

4-2.6.2 Hoods and enclosures shall be connected to a high-efficiency cyclone(s) and blower located outdoors.

4-2.6.3 The cyclone exhaust shall terminate in a safe outside location.

4-2.6.4 All components of a dust collection system shall be made of conductive materials and shall be watertight.

4-2.6.5 The ductwork, cyclone, and fan system shall be designed such that the concentration of magnesium dust in the system is less than 25 percent of the lower flammable limit (LFL).

4-2.6.6 The minimum length of duct from the dust-producing operation(s) to the cyclone shall be 15 ft (4.6 m).

4-2.6.7 The use of media-type collectors shall be prohibited.

4-2.6.8 Explosion venting shall be permitted to be installed on dry-type dust collection systems.

4-2.6.9 Connecting ducts or suction tubes shall be completely grounded and bonded, with no unnecessary bends. Ducts shall be fabricated and assembled, and shall have a smooth interior and internal lap joints pointing in the direction of airflow. Ducts shall have no unused capped side outlets, pockets, or other dead-end spaces that can allow an accumulation of dust.

4-2.6.10 Where practical, the dust collection system shall be designed and installed so that the dust is collected upstream of blowers.

4-2.6.11 Each dust-producing machine shall be equipped with its own dust-separating unit.

Exception: With multiunit machines, two dust-producing machines shall be permitted to be served by a single separator. Where multiunit machines are in use, only magnesium shall be processed in each unit.

4-2.6.12 The power supply to dust-producing machines shall be interlocked with the exhaust blower. The interlock system shall function under conditions of drive belt failure.

4-3 Cleaning.

4-3.1 Systematic cleaning of the entire grinding area, including roof members, pipes, conduits, etc., 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* Electrical equipment and wiring methods associated with dust-producing machines, including those used in connection with dust collection equipment, shall be approved for Class II, Group E atmospheres and shall be installed in accordance with Article 502 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 shall be kept clean and free from dust. 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. Where this type of work is done in such areas, all machinery in the area 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.

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 where 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* Serious local friction heating of bearings in any machine located in an area containing a dust hazard shall be prevented.

5-2 Requirements for Machinery.

5-2.1 All dust-producing machines and conveyors shall be constructed so that escape of 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 suitable 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 Containers approved by the U.S. Department of Transportation (DOT) for shipment of magnesium powders shall be used where magnesium powder is transported on pallets by industrial trucks. (*See NFPA 505, Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, 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 lower flammable limit (LFL) of the magnesium dust at normal operating conditions. (*See Section 4-2 and Appendix B.*)

6-2.2* If an inert gas such as argon or helium is used, it shall have an oxygen concentration appropriate to the inerting gas and the particle size of the magnesium dust. Recycling of inert gas shall be permitted. (*See NFPA 69, Standard on Explosion Prevention Systems.*)

6-2.3 The conveying gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

6-2.4 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. Higher conveying velocities are more desirable and increase safety.

6-3 Ductwork for Conveying Systems.

6-3.1* Explosion vents, openings protected by antiflashback swing valves, or rupture diaphragms shall be provided on ductwork. Relief shall be to a safe location. The guidelines in NFPA 68, *Guide for Venting of Deflagrations*, do not apply to ductwork for conveying systems for magnesium powder.

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). (*See NFPA 69, Standard on Explosion Prevention Systems.*)

6-3.2.1 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 fabricated 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 charge.

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

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 material.

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 manufacturing buildings wherever practical.

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

6-5 Dust Collectors.

6-5.1 High-efficiency cyclone magnesium dust collectors shall be located in and exhausted to a safe outside location, and shall be provided with suitable barricades or other means for protection of personnel and facilities.

6-5.2 Ductwork shall comply with the provisions of Section 6-3.

6-5.3* 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.

Chapter 7 Prevention of 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 The use of water for cleaning shall not be allowed in manufacturing areas unless the following requirements are met.

(a) It has been determined by competent technical personnel that the use of high-pressure water will be the safest and most effective method of cleaning.

(b) Operating management has full knowledge of and has granted approval for its use.

(c) Adequate ventilation, either natural or forced, is available to maintain the hydrogen concentrations safely below the lower flammable limit (LFL).

(d) Complete drainage of all water and powder to a safe, remote area is available.

(e) The area has been cleaned to remove all loose accumulations of powder.

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 1,000,000 lb (453,600 kg).

8-1.2.4 Aisle widths shall be not less than one-half the height of the piles, but in no case shall they be less than 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.

8-1.2.7 No cutting, welding, or burning shall be permitted without operating management approval.

8-1.3 Indoor Storage.

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

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

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

8-1.3.3 Supports used under piles of magnesium ingots shall be noncombustible. There shall be no idle pallet storage.

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 500,000 lb (226,800 kg).

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

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 inspected prior to storage to see that they are clean and free of chips or fine particles of magnesium.

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 cu ft (36 m^3). Aisles shall be maintained to permit inspection and effective use of fire protection equipment.

8-2.5 Aisle widths shall be not less than one-half the height of the piles.

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 cu ft (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 not be less than one-half the height of the piles.

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 Mills, Warehouses, and Processing Plants.

8-4.1 Buildings 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.

8-4.2 Magnesium shall not be stored in or over a basement or similar subgrade space.

8-4.3 Stocks of magnesium shall be stored separately from other combustible materials.

8-4.4* Automatic sprinkler protection shall be permitted to be installed in magnesium storage buildings where combustible cartons, crates, or packing materials are present.

8-5 Storage in Racks or Bins.

8-5.1 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.

8-5.2 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 act as shields against sprinkler discharge.

8-6 Storage of Scrap Magnesium.

8-6.1 This section shall apply to the storage of scrap magnesium in the form of chips, turnings, swarf, or other fine particles.

8-6.2 Buildings shall be of noncombustible construction.

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

8-6.3 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 to avoid the fines from becoming wet.

8-6.4* Wet magnesium scrap (chips, fines, swarf, or sludge) shall be kept under water in a covered and vented steel container in an outside location. Sources of ignition shall be kept away from the drum vent and top. Containers shall not be stacked.

8-6.5* Storage in quantities greater than 50 cu ft (1.4 m^3) (six 55-gal drums) shall be kept separate from other occupancies by fire-resistive construction without window openings or by an open space of at least 50 ft (15 m). Such buildings shall have explosion vents.

8-6.6 The use of automatic sprinklers in scrap magnesium storage buildings or areas shall be prohibited.

8-6.7 Suitable fire extinguishment materials shall be readily available in these locations.

8-7* Storage of Solid Magnesium Scrap.

8-7.1 Solid magnesium scrap, such as clippings and castings, shall be stored in noncombustible bins or containers pending salvage.

8-7.2 Oily rags, packing materials, and similar combustibles shall not be permitted in storage bins or areas storing solid magnesium scrap.

8-7.3* Solid scrap shall be treated in accordance with Section 8-6 or 8-7.

8-8 Storage of Magnesium Powder.

8-8.1 Buildings used to store magnesium powder shall be of noncombustible single-story construction.

8-8.2 The use of automatic sprinklers in such buildings shall be strictly prohibited.

8-8.3 Magnesium powder shall be kept well separated from other combustible or reactive metals.

8-8.4 Magnesium powder shall be stored in steel drums or other closed containers. The containers shall be kept tightly sealed and stored in dry locations.

8-8.5 As necessary, magnesium powder storage areas shall be checked for water leakage.

8-8.6 Areas that routinely are used for the storage of magnesium powder shall be considered Class II, Group E, in accordance with NFPA 70, *National Electrical Code*.

8-8.7 Suitable fire extinguishment material shall be readily available in these locations.

8-8.8 Where magnesium powder in drums is stacked for storage, the maximum height shall not exceed 18 ft (5.5 m). Stacked storage shall be done in such a manner so as to ensure stability. Under no circumstances shall containers be permitted to topple over. The safest manner of storage is achieved using no stacking.

8-9 Storage of Finished Products.

8-9.1 This section shall apply to the storage of magnesium, in warehouses, wholesale facilities, and retail outlets, in the form of finished parts in which magnesium makes up the major portion of the articles on a volumetric basis.

8-9.2 Storage in quantities greater than 50 cu ft (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.

8-9.3 Magnesium products stored in quantities greater than 1000 cu ft (28 m^3) shall be separated into piles each not larger than 1000 cu ft (28 m^3), with the minimum aisle width equal to the height of the piles.

8-9.4* Where storage in quantities greater than 1000 cu ft (28 m^3) is contained in a building of combustible construction, or the magnesium products are packed in combustible crates or cartons, or there is other combustible storage within 30 ft (9 m) of the magnesium, the storage area shall be protected by automatic sprinklers.

Chapter 9 Fire Fighting Procedures

9-1 General Precautions.

9-1.1 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). Under no circumstances shall the use of water, halogenated agents (halon), carbon dioxide, foam, or nitrogen be permitted.

Exception: A few individual burning chips of magnesium shall be permitted to be extinguished by dropping them into a bucket of water.

9-1.2 Magnesium solids and heavy magnesium castings normally do not ignite until reaching the melting point of magnesium. Extreme caution shall be taken to avoid molten magnesium contacting water, as an explosion will occur.

9-1.3* 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. This is due to 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). Application of wet extinguishing agents accelerates a magnesium fire and could result in an explosion.

9-1.4 The use of automatic sprinklers shall not be permitted in areas where molten magnesium is produced or handled, in areas where heat-treating furnaces are located, or in areas where magnesium chips or powders are produced or handled.

9-2 Reignition Conditions. Extreme care shall be exercised even after a magnesium fire appears to be out. Reignition can occur due to high temperatures of the magnesium beneath the extinguishing agent, especially if the magnesium or the extinguishing agent covering the magnesium is disturbed. This allows air to reignite the magnesium.

9-3 Automatic Sprinkler Protection. Automatic sprinkler protection shall only be permitted in storage areas for heavy or light magnesium castings in accordance with Sections 8-2, 8-3, and A-8-7.

9-4 Emergency Procedures. Employees shall be instructed and trained in fighting magnesium fires using the permissible techniques appropriate for the various physical forms of magnesium. Employees shall be instructed in emergency procedures to be followed in the event of a fire.

9-5 Fire Fighting Organization. Any fire fighting organizations that respond to an emergency shall be trained in the hazards involved in fighting a magnesium fire.

9-6 Employee Instruction.

9-6.1 All employees shall be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.

9-6.2 All employees shall be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire extinguishing equipment.

9-6.3 The hazards posed by causing dust clouds and the danger of applying liquids onto an incipient fire shall be explained.

9-6.4 Strict discipline and scrupulous housekeeping shall be maintained at all times.

9-6.5 Attention shall be given to employee training and organizational planning to ensure safe and proper evacuation of the area.

9-7 Periodic Inspection.

9-7.1 A thorough systematic inspection shall be made at regular intervals not to exceed 1 month.

9-7.2 At least two or more competent persons shall conduct each inspection, and their findings and recommendations shall be permanently recorded in the plant's principal office.

9-7.3 The inspection shall include the following:

(a) General safety precautions

(b) Fire fighting equipment

(c) First-aid equipment

(d) Housekeeping

(e) Electrical and mechanical equipment

(f) Procedures.

9-7.4 Indicating and recording instruments and alarm devices shall be checked daily and the results recorded. Instruments shall be calibrated every 6 months.

Chapter 10 Referenced Publications

10-1 The following documents or portions thereof are referenced within this document and shall be considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

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

NFPA 69, *Standard on Explosion Prevention Systems*, 1992 edition.

NFPA 70, *National Electrical Code*, 1993 edition.

NFPA 80, *Standard for Fire Doors and Fire Windows*, 1992 edition.

NFPA 86, *Standard for Ovens and Furnaces*, 1990 edition.

NFPA *101, Life Safety Code*, 1991 edition.

NFPA 220, *Standard on Types of Building Construction*, 1992 edition.

NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*, 1992 edition.

NFPA 650, *Standard for Pneumatic Conveying Systems for Handling Combustible Materials*, 1990 edition.

10-1.2 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

ASTM E136, *Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750°C*, 1992 edition.

Appendix A Explanatory Material

This Appendix is not a part of the requirements of this NFPA document, but is included for information purposes only.

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-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 497B, *Recommended Practice for the Classification of Class II 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-3-2 Extreme care should be taken when heat treating aluminum containing 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.

A-3-2.4 To further 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-3-2.8 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 auto-ignition temperatures than either parent metal.

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 ½ 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 65, *Standard for the Processing and Finishing of Aluminum.*

A-4-2.6.1 The maximum concentration of less than 100 mesh magnesium dust should never exceed 0.03 oz per cu ft (0.03 g/L) (air), which is the lower flammable limit (LFL).

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

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 497B, *Recommended Practice for the Classification of Class II 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-4-6.4 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 may be anticipated.

A-5-2.2 See NFPA 77, *Recommended Practice on Static Electricity.*

A-5-2.3 Bearings located outside of the volume containing magnesium dust are preferred. Bearings within the volume containing magnesium dust are potential sources of ignition in the event of a failure. Bearings should be located outside the 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-6-3.1 See NFPA 68, *Guide for Venting of Deflagrations.*

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

A-6-4.1 Wherever practical, the design should not allow the transported dust or powder to pass through the fan before entering the final collector. Where practical, fans should be located outside of all manufacturing buildings.

A-6-5.3 See NFPA 77, *Recommended Practice on Static Electricity.*

A-7-2.1 See NFPA 497B, *Recommended Practice for the Classification of Class II 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 Fire Hazards of Materials.* This serves as a warning to fire fighters of the potential risk in the event of an emergency.

A-8-1.3.2 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-8-2 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 may ignite spontaneously.

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, producing 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-8-4.4 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium, producing 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-8-6.4 The wet magnesium should be checked frequently to ensure that it remains totally immersed during storage.

A-8-6.5 For design information, see NFPA 68, *Guide for Venting of Deflagrations.*

A-8-7 The danger of ignition of this solid scrap is very low, provided it is not stored with combustible materials. However, automatic sprinkler protection is recommended.

A-8-7.3 Scrap magnesium is usually received by secondary smelters in truck or carload quantities. Solid scrap may be shipped loose, but chips and turnings are packed in covered steel drums. Since storage is in the open, incipient fires can be readily detected and extinguished.

A-8-9.4 A slow-burning fire in nearby combustible material can develop enough heat to ignite thin-section magnesium, producing 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-9-1.3 Recommended extinguishing agents for magnesium are approved Class D agents, gases (SO_2, SF_6/CO_2, Ar, He), and nonreactive granular material or powders. In cases involving molten magnesium burning, dry magnesium foundry flux can be used as an extinguishing agent. The flux melts or crusts over the hot metal, excluding air from the burning metal. Magnesium foundry flux has been shown to be an effective extinguishing agent. Protective gas mixtures are useful only if the magnesium vessel is closed.

Appendix B Supplementary Information on Magnesium

This Appendix is not a part of the requirements of this NFPA document, but is included for information 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. 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, etc., 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, the piece tested is magnesium.

B-3.1 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 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 ignitability 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, feather-like 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 electrostatic 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 electrical 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 D2240, 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, with the test leads interchanged at the instruments between the two measurements. The average of the two measurements is taken as the resistance to ground at that location. Measurements are customarily taken with the electrode or electrodes more than 3 ft (0.9 m) from any ground connection or grounded object resting on the floor.[1]

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, ignitable 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 relatively massive; they seldom ignite due to their relatively 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 where in contact with burning magnesium chips or where 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.

[1] 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.

While 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 While 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 approach a fire closely 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 information purposes only.

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-1 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), 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-1. 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 manufacture 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-1 Explosion Characteristics of Unalloyed Magnesium Dust in Air [200 Mesh (74 microns)]

Explosibility Index*	10
Ignition Sensitivity†	3.0
Explosion Severity††	7.4
Maximum Explosion Pressure (psig)	115 (793 kPa gauge)
Maximum Rate of Pressure Rise (psi/sec)	15,000 (103,410 kPa/sec)
Ignition Temperature Cloud (°C)	560°C
Minimum Cloud Ignition Energy	
Joules (watt-seconds)	0.04
Minimum Explosion Concentration (oz/cu ft)	0.03
Limiting Oxygen % for Spark Ignition	—§

(K_{St} values for specific particle sizes)

* Explosibility Index = ignition sensitivity × explosion severity

† Ignition Sensitivity =

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

†† Explosion Severity =

$$\frac{[\text{Max exp. pressure} \times \text{max rate of pressure rise}]\ \text{Pittsburgh coal dust}}{[\text{Max exp. pressure} \times \text{max rate of pressure rise}]\ \text{Sample dust}}$$

§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 where 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, etc. 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. (20-cm) concrete block wall to fail. It is obvious that this overpressure is reached extremely rapidly where the rate 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 LFL of 0.03 oz/cu ft (0.03 g/L) shown in Table C-1. 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 ignitable level. Care should be taken, however, to maintain sufficient superficial air velocity [over 3500 ft/sec (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/cu ft (0.03 g/L) flammability level, the airflow is calculated as follows:

$$\text{Air Needed} = \frac{10 \text{ lb/min} \times 16 \text{ oz}}{0.03 \text{ oz/cu ft}} = 5333.3 \text{ CFM}$$

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

$$Q = AV$$

where Q = quantity of airflow
A = cross-sectional area
V = velocity

$$Q = \frac{5333.3}{1.068} = 4994 \text{ ft/min}$$

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 nonignitable dust concentration, the amount of air needed per pound of powder $\left[\frac{(5333.3 \text{ CFM})}{10 \text{ lb}} \times 0.075 = 40 \text{ lb}\right]$ is quite large.

The standard density of dry air is taken at 0.075 lb/cu ft.

Therefore, highly diluted phase-conveying is necessary for safe operation. With the added recommended safety factor of 2 to 3, this ratio becomes much greater. Observing these guidelines provides a simple starting point for the design of a reasonably safe system for air-conveying fine magnesium powder.

In air-separating cyclones, the dust concentration can be assumed to approximate the concentration in the conveying lines less an allowance of 10 percent for air-lock leakage, etc. Nearly all of the conveying air entering a cyclone leaves through the vent, and there are no semistagnant air spaces except for the small volumes of the dust trap and dip-leg.[1] As a consequence, the concentration of magnesium fines [less than 100 mesh (less than 149 microns)] in the air in a properly designed cyclone separator does not exceed the lower flammability limit in such units where the recommended safety factor and other considerations referred to previously are used as guidelines.

With regard to the presence of ignition sources of sufficient strength to ignite a dust cloud, if the lower flammability level of 0.03 oz/cu ft (0.03 g/L) is exceeded, it should be noted that the 40 millijoules (MJ) energy required to ignite such a dust cloud is nearly 20 to 50 times greater than that required to ignite flammable gas or vapor mixtures. Such strong ignition sources do not generally exist in magnesium powder plants that operate with lightning protection and electrically bonded and grounded equipment to minimize static electricity, and that have strong magnetic separators to remove tramp metals from process streams, where all the above safety equipment and arrangements are regularly inspected and maintained.

C-2 Chemical Process to Render Magnesium Fines Noncombustible. Metallic magnesium fines generated in the production of structural magnesium parts or other products often have no commercial value and can present a fire

[1]Attention is directed to the difference between this situation and a grain silo, where a large amount of dust is discharged by gravity from the separator into semistagnant air in a large cylindrical tank or silo, which allows the dust concentration to materially increase.

hazard. They should be disposed of regularly. These fines might be the wet fines from a dust collector system, partially converted to an inactive state by having been collected in water, or chips from a machining operation. Chips and turnings may be wet, dry, or oil-soaked, and, frequently, they are contaminated. Fines vary in size from the dust generated in a sanding or buffing operation to a much larger particle produced by sawing, drilling, or turning. Prior to disposing of any fines, a secondary processor/melter should be contacted to assess the recycled value of the by-product.

In seeking a means of disposal for magnesium fines, other than by burning, the most obvious solution is to immerse them in water. Magnesium fines can be rendered partially inactive by reacting them with water to form hydrogen and noncombustible magnesium hydroxide. Film formation on the magnesium, however, normally slows the process beyond practical limits; however, once substantially reduced to magnesium hydroxide, the residual sludge does not burn and can be disposed of like any other inert material. It has been found that partially inactivated magnesium fines containing approximately 10 percent metallic magnesium do not burn.

Magnesium sludge can more effectively be rendered chemically inactive and noncombustible by reacting it with a 5 percent solution of ferrous chloride ($FeCl_2 \bullet 2H_2O$). The reaction takes place with the evolution of hydrogen at such a rate that the magnesium fines are changed in less than 24 hours to a concentration of magnesium hydroxide that the residue cannot burn. Since hydrogen is generated by the reaction, the process should be carried out in an open container placed outside in a location where natural air movement will prevent the accumulation of explosive concentrations of hydrogen in air. Open flames and smoking should be prohibited in the immediate vicinity of the process. The amount of $FeCl_2 \bullet 2H_2O$ commonly employed in the decomposition is approximately 0.6 lb (0.3 kg) for each pound of magnesium fines (dry weight). The amount of water in the fines should be considered in determining the weight of the magnesium fines. Exact concentrations should be determined on the basis of the type of fines being handled. The cycle can be repeated easily in the same container until the amount of brown, damp residue is such that the container should be cleaned out. To be certain of complete reaction, a sample of the residue should be heated with a Bunsen burner or oxyacetylene torch to determine if it can be ignited. While the method is simple, it should be operated under strict technical supervision to avoid disposal of partially reacted magnesium.

The main constituent of the residual sludge is magnesium hydroxide [$Mg(OH)_2$], which indicates that the iron salt functions not as a reagent that is consumed in the reaction, but rather as a catalyst that simply promotes the reaction with water to form magnesium hydroxide and hydrogen gas. Considerable heat is generated in the early stages of the reaction, especially if the particles are finely divided and clean. During this stage, considerable hydrogen is released and foaming can occur. Small amounts of hydrogen continue to evolve until no metallic magnesium is present.

It should be remembered that this is a chemical reaction and the results obtained depend on several factors. It has been mentioned that freshly formed, finely divided particles react quite quickly, so that considerable heat, hydrogen evolution, and foaming can occur. In case of excessive foaming, the reaction should be slowed down, or a defoamer can be added. If the fines have been under water in a collector system for some time, less metallic magnesium is present, and the reaction is slower. Particles coated with oil or tar pose special problems, and the use of a detergent might be advisable. If the reaction is carried out in a container that has little surface area and limited excess water, the heat of reaction might be sufficient to ignite the hydrogen. Hydrogen is less liable to be trapped in a shallow container, and a larger surface area provides better heat dissipation.

It is recommended that the details of the process be worked out by technically competent personnel. The daily operation can be performed on a routine basis under technical supervision. If excessive heating is a problem, more water can be added. It has been found that a weaker solution will frequently render the material noncombustible in the desired length of time with less initial heating. The reaction vessel can be mild steel. In one case, a tank constructed of $^1/_4$-in. (6.4-mm) thick mild steel, in almost constant use, lasted 10 years before leaking.

Ferric chloride ($FeCl_3$) in dilute amounts can be used in place of ferrous chloride ($FeCl_2$) to produce the same results. The initial rate of reaction is faster when using ferric chloride; however, this can be controlled by adding more water or initially adding the magnesium fines slowly. Solutions of $FeCl_3$ in water as low as 1 percent dilute have been used to render certain types of magnesium fines noncombustible within 24 hours.

$FeCl_3$ is available in crystalline form ($FeCl_3 \bullet 6H_2O$) or the anhydrous form (98 percent $FeCl_3$). Either can be used, but the anhydrous form should be handled like an acid because of the hazard posed by chemical burns to the skin and eyes. In figuring the required amounts of either $FeCl_2$ or $FeCl_3$, the water produced by crystallization should be considered in determining the strength of the solution.

Several companies have used either $FeCl_2$ or $FeCl_3$ to render magnesium fines noncombustible. The general experience supports the original work done on a laboratory scale. The following two examples provide information of interest.

Case 1

Material Treated: Fines from wire brushing sheet collected in a wet dust collector or fine shavings from a milling operation.

Tank Size: 8 ft (2.4 m) wide × 20 ft (6.1 m) long × 27 in. (69 cm) deep.

Amount of Fines Treated: Amount of fines in water solution varies considerably from batch to batch. Several hundred pounds have been treated at a time.

Amount of Chemical Added: 25 lb (11.4 kg) of $FeCl_2 \bullet 6H_2O$ or 15 lb (6.8 kg) of anhydrous $FeCl_3$ (98 percent $FeCl_3$) per 100 gal (379 l) of liquid in the tank. $FeCl_2 \bullet 2H_2O$ is added as a powder; $FeCl_3 \bullet 6H_2O$ is added in cake form; the 98 percent $FeCl_3$ is a powder and is made up as a water solution and pumped into the tank.

Result: Little heat evolution, low foaming, and a noncombustible sludge within 24 hours.

NOTE: The reaction is carried on outside, and a steam coil is used to warm the solution in the winter. The residue is checked with a propane torch to determine combustibility. Adequate protection from chemical burns is provided where using anhydrous $FeCl_3$ (98 percent).

Case 2

Material Treated: Fines generated by sanding of magnesium die castings that have been collected in a wet dust collector.

Tank Size: 5 ft (1.5 m) wide × 8 ft (2.4 m) long × 3½ ft (1 m) deep (steel dumpster box).

Amount of Fines Treated: Approximately 60 lb (27 kg) magnesium fines in a 55-gal (208-l) drum filled with fines and water. To this is added approximately 92 gal (348 l) of water that results in a liquid depth of 5 in. (12.7 cm) in the tank.

Amount of Chemical Used: 44 lb (20 kg) of 98 percent $FeCl_3$ added with an aluminum hand scoop.

Result: Some heat evolution, foaming, and a noncombustible sludge within 24 hours.

NOTE: If too much ferric chloride is used at once, the reaction is quite violent. Where 100 lb (45.4 kg) of magnesium fines were treated, the foam overflowed the tank. Each lot is tested for combustibility with a propane torch. The operator is protected against chemical burns while adding the $FeCl_3$ to the solution.

The following generalizations taken from the experience of users provides further information of interest.

(a) The magnesium fines can be added to the solution or the solution added to the fines. Additional fines can be added to a previous batch containing inactivated sludge. Experience indicates the time needed to complete each reaction and the amount of either $FeCl_2$ or $FeCl_3$ that needs to be added with each increment of fines.

(b) The ratio of $FeCl_2$ or $FeCl_3$ to magnesium content is subject to alteration based on a number of conditions, but the reaction takes place over a broad range of concentrations. The amount required should be determined for the fines being treated and the time allowed for reaction. The recommendation is to use 0.6 lb (0.3 kg) of $FeCl_2 \bullet 2H_2O$ for each pound of magnesium fines (dry weight). The upper limit on concentration used has been 5 percent, but in many cases a lower concentration has been satisfactory and has produced less initial heat and foaming.

(c) Personnel handling anhydrous ferric chloride or ferric chloride solutions should wear overalls, rubber aprons, rubber gloves, and chemical goggles.

(d) Moist fines should not be flushed through long lines because they can build up a layer of semimoist material in the pipe. Inert sludge does not create a fire hazard under these same conditions.

(e) Heating with a steam line has been used to speed up the reaction process, especially in winter and after the initial rapid reaction stage is over.

(f) Foaming can be decreased by the use of defoaming agents. A greater quantity of water limits the heating and slows down the formation of foam.

(g) Longer reaction times might be needed to inactivate larger particles or those that are covered with oil or tars.

(h) For the purpose of estimating metal content, a cu ft (m^3) of material taken from a wet dust collector should be assumed to contain approximately 30 lb (13.6 kg) of metallic dust and 6 gal (23 L) of water. Approximate weights used for dry fines are 50 lb per cu ft (800 kg/m^3) of sawdust and 15 lb per cu ft (240 kg/m^3) of rotary filings.

(i) Particular care should be taken in adding the initial ¼ lb to ½ lb (0.11 kg to 0.22 kg) of magnesium fines per pound of $FeCl_2$ or $FeCl_3$ content of the solution. During this period, the reaction rate can be very rapid with fine powders (60 to 80 percent completion in 5 minutes), due to the initial acidity of the iron chloride salts. Beyond this point, however, the reaction rate moderates to a stable 4 to 5 percent of completion every 5 minutes (50 to 60 percent per hour).

(j) If magnesium and aluminum fines are mixed, the magnesium still reacts with the ferrous chloride or ferric chloride solution.

(k) Partially deactivated fines containing 10 percent metallic magnesium do not support combustion.

(l) After reaction is complete, the inert residue should be disposed of as waste or fill material.

Although this method has been widely used in the past, current environmental regulations should be met; therefore, a review with local authorities should be conducted to ensure compliance with all local, state, and federal requirements.

Appendix D Referenced Publications

D-1 The following documents or portions thereof are referenced within this document for informational purposes only and thus are not considered part of the requirements of this document. The edition indicated for each reference is the current edition as of the date of the NFPA issuance of this document.

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

NFPA 13, *Standard for the Installation of Sprinkler Systems*, 1991 edition.

NFPA 65, *Standard for the Processing and Finishing of Aluminum*, 1993 edition.

NFPA 68, *Guide for Venting of Deflagrations*, 1988 edition.

NFPA 77, *Recommended Practice on Static Electricity*, 1993 edition.

NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1991 edition.

NFPA 704, *Standard System for the Identification of the Fire Hazards of Materials*, 1990 edition.

D-1.2 Other Publications.

D-1.2.1 ASTM Publication. American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*, 1991 edition.

D-1.2.2 U.S. Bureau of Mines Publication. U.S. Bureau of Mines, Cochrans Mill Road, Pittsburgh, PA 15236-0070.

RI 6516, "Explosibility of Metal Powders," M. Jacobson, A.R. Cooper, and J. Nagy, 1964.

D-1.2.3 U.S. Government Publication. Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

49 CFR, *Code of Federal Regulations*, Parts 100-199.

D-1.2.4 Additional Publications.

Bartknecht, W., "Explosions Pressure Relief," Chemical Engineering Progress, 11th Loss Prevention Symposium, Houston, 1977.

Bartknecht, W., *Exploseonen*, 1979 Springer-Verlog Berlin, Heildeberg, NY.

Bartknecht, W., "Report on Investigations on the Problem of Pressure Relief of Explosions of Combustible Dusts in Vessels," Staub Reinhalt, Luft, Vol. 34, No. 11, Nov. 1974, and Vol. 34, No. 12, Dec. 1974.

Bodurtha, F.T., *Industrial Explosion, Prevention and Protection*, McGraw Hill, New York, 1980.

"Combustible Dusts," Loss Prevention Data Sheet 7-76, 1976, Factory Mutual Research Corp., Norwood, MA.

Donat, C., "Pressure Relief as Used in Explosion Protection," Chemical Engineering Progress, 11th Loss Prevention Symposium, Houston, 1977.

Fire Protection Handbook, 17th ed., National Fire Protection Association, Quincy, MA, 1991.

"Industrial Ventilation: A Manual of Recommended Practice," 21st ed., Lansing, MI, American Conference of Governmental Industrial Hygienists, 1991.

Palmer, K.N., *Dust Explosions and Fires*, Chapman & Hall, London, 1973.

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