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NFPA 651 Manufacture of Aluminum Powder 1993 Edition

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

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The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

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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Attn: Product Development

NFPA 651

Standard for the

Manufacture of Aluminum Powder

1993 Edition

This edition of NFPA 651, *Standard for the Manufacture of Aluminum Powder*, 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.

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

Origin and Development of NFPA 651

NFPA 651, *Manufacture of Aluminum Powder*, was originally prepared by the Committee on Dust Explosion Hazards in 1938 and 1939. It was first adopted in 1939, and revised in 1946, 1952, 1959, 1963, 1967, and 1972. The 1967 edition was approved by the American National Standards Institute in 1967 and designated ANSI Z12.11.

NFPA 652, *Plants Producing or Handling Magnesium Powder*, was originally prepared by the Committee on Dust Explosion Hazards in 1942 and was first adopted in 1944. Amendments were adopted in 1945, 1946, 1952, 1959, and 1968. The 1968 edition was approved by the American National Standards Institute in 1968 and designated ANSI Z12.15.

In 1973 NFPA 651 and 652 were combined into a single standard, NFPA 651-T, and tentatively adopted at the 1973 Annual Meeting and officially adopted at the 1974 Annual Meeting. Revisions were adopted in 1980 and 1987.

For this 1993 edition, the Committee has added definitions, clarified the requirements for the location of aluminum powder production plants, revised the requirements for electrical power, machinery and operations, and for in-plant conveying of aluminum powder including the provisions for inert conveying. The requirements for explosion venting, manual fire fighting, and automatic sprinkler protection were also updated. This includes the change in terminology from "light metal powder" to "aluminum powder" to emphasize that the requirements for the manufacture of magnesium powder have now been incorporated into the 1993 edition of NFPA 480, *Standard for the Storage, Handling and Processing of Magnesium Solids and Powders*. The Committee has incorporated various style and editorial 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 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 651

Standard for the

Manufacture of Aluminum Powder

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 9 and Appendix C.

Chapter 1 General

1-1 Scope.

1-1.1* This standard shall apply to manufacturing facilities that produce aluminum flake powder, aluminum paste, atomized aluminum powder or aluminum granules, or any aluminum alloy powder that is combustible or explosive in an ambient atmosphere.

1-1.2 This standard shall not apply to the production of waste metal dust by operations such as grinding, buffing, and polishing of semifinished aluminum products. (*See NFPA 65, Standard for the Processing and Finishing of Aluminum.*)

1-1.3 This standard does not apply to the transportation of aluminum powder on public highways, waterways, or by air or rail.

1-2 Purpose. The objective of this standard is to minimize the occurrence of and resulting damage from fire and explosion in areas where aluminum powder products are manufactured.

1-3 Retroactivity. Unless otherwise stated, the requirements of this standard shall not be applied retroactively.

1-4 Equivalent Protection.

1-4.1 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 will be created or continued through noncompliance.

1-4.2 This standard is not intended to prevent use of systems, methods, or devices that provide equivalent protection from fire and explosion. NFPA 69, *Standard on Explosion Prevention Systems*, shall be referred to when considering the use of optional systems.

1-5 Definitions.

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."

Combustible Aluminum Dust.* Any finely divided aluminum material 420 microns or smaller in diameter (material passing a U.S. No. 40 Standard Sieve) that presents a fire or explosion hazard when dispersed and ignited in air.

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.

Shall. Indicates a mandatory requirement.

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

Chapter 2 Location and Construction of Aluminum Powder Production Plants

2-1 Location.

2-1.1 Aluminum powder production plants shall be located on a site large enough so that the buildings in which powder is manufactured are at least 300 ft (90.9 m) from public roads and from any occupied structure, such as public buildings, dwellings, business or manufacturing establishments, other than those buildings that are a part of the aluminum powder production plant.

2-1.2 Different powder production systems shall be located in separate buildings located at least 50 ft (15.2 m) from each other.

Exception: Two buildings less than 50 ft (15.2 m) apart shall be permitted if the facing walls 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.

2-2 Security.

2-2.1 This section shall be applied to new and existing facilities.

2-2.2 The site on which the powder production plant is located shall be surrounded by strong fencing at least 6 ft (2 m) high with suitable entrance gates.

2-2.3 All gates that are not kept locked shall be under supervision.

2-3 Building Construction.

2-3.1 All buildings used for the manufacture, packing, or loading for shipment of aluminum powders shall, where practical, 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.

2-3.2 All buildings used for the manufacture of aluminum powders shall be subdivided into as many small units as practical by pressure-resistant, nonload-bearing, noncombustible, dusttight walls.

2-3.3 All walls of 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 aluminum powder can infiltrate and accumulate.

2-3.4 Floors shall be hard-surfaced and nonslip, installed with a minimum number of joints in which aluminum powder can collect. The requirements of this section shall also apply to elevated platforms, balconies, floors, or gratings. (*See Appendix B.*)

2-3.5 Roofs of buildings that house dust-producing operations shall be supported on girders or structural members designed to minimize surfaces on which dust can collect. Where such surfaces are unavoidably present, they shall be covered by a smooth concrete, plaster, or noncombustible mastic fillet having a minimum slope of 55 degrees to the horizontal.

2-3.6 Roof decks shall be watertight.

2-3.7* Explosion venting shall be provided where aluminum powder is processed and handled. Handling does not include storage in closed containers.

2-4 Doors and Windows.

2-4.1 All door and window frames shall be metal.

2-4.2 Each room shall have at least two widely separated exits to exit corridors or to the outside. All doors in interior fire-rated partitions shall be approved self-closing fire doors, installed in accordance with NFPA 80, *Standard for Fire Doors and Fire Windows*. Hardware for emergency exit doors shall conform to requirements of NFPA 80 and of NFPA *101®*, *Life Safety Code®*. (*See Section 5-11 and Chapter 14 of NFPA 101.*)

2-4.3 Emergency exit doors shall be provided from all areas, including balconies and elevated platforms.

2-4.4 Where two buildings are less than 50 ft (15.2 m) apart, only one of the facing walls shall have windows and doors. (*See also Exception to 2-1.2.*)

2-5 Communication Between Buildings.

2-5.1* Where buildings are separated by not less than 50 ft (15.2 m) or where small units of one major process section communicate through enclosed passageways, such passageways shall be of noncombustible construction and be specifically designed to relieve internal pressure from an explosion and shall be protected by automatic self-closing 3-hour fire doors.

2-5.2 All enclosed passageways shall be provided with adequate means of egress as provided by NFPA *101*, *Life Safety Code*.

2-6 Grounding and Lightning Protection.

2-6.1* All process equipment and all building steel shall be bonded and grounded in accordance with NFPA 780, *Lightning Protection Code*, and NFPA 70, *National Electrical Code®*.

2-6.2 Lightning rods shall be provided for all boiler stacks and chimneys and for the high points of all buildings.

2-6.3 Power lines shall be adequately protected against lightning. (*See NFPA 780, Lightning Protection Code.*)

2-6.4 A lightning arrestor system shall be provided around or within the building area of such capacity as to fully protect all buildings from lightning.

2-7 Electrical Power.

2-7.1 All electrical equipment and wiring shall be installed in accordance with NFPA 70, *National Electrical Code*.

2-7.1.1 All parts of powder manufacturing buildings shall be considered Class II, Group E locations.

Exception No. 1: Offices and similar areas so occupied and segregated as to be reasonably free from dust and so classed by the authority having jurisdiction.

Exception No. 2: Control equipment meeting the requirements of NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment.

NOTE: For additional information on classification of dusty locations, see NFPA 497B, *Recommended Practice for the Classification of Class II Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

2-7.1.2 Wet solvent milling areas shall be considered Class I, Group D locations.

Exception No. 1: Offices and similar areas so occupied and segregated as to be reasonably free from solvent vapors and so classed by the authorities having jurisdiction.

Exception No. 2: Control equipment meeting the requirements of NFPA 496, Standard for Purged and Pressurized Enclosures for Electrical Equipment.

NOTE: For additional information on classification of areas containing solvent vapors, see NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas.*

2-7.2 Provisions shall also be made for remote manual cutoff of all electrical power to manufacturing areas from one or more central locations, such as offices, guard's booth, or other appropriate locations.

2-7.3 All manufacturing buildings shall be provided with emergency lighting systems in accordance with Section 5-9 of NFPA *101, Life Safety Code.*

2-7.4 Electrical equipment shall be inspected and cleaned at least once each year or more frequently if conditions warrant.

2-7.5 Flashlights and storage battery lamps shall be listed for the locations in which they are used.

Chapter 3 Machinery and Operations

3-1 General Precautions.

3-1.1 This chapter shall be applied to new and existing facilities.

3-1.2 In powder handling or manufacturing buildings and in the operation of dust-conveying systems, precautions shall be taken to avoid the production of sparks from static electricity, electrical faults, or impact (e.g., iron or steel articles on stones, on each other, or on concrete).

3-1.3 Water leakage in or into any building where it can contact aluminum powder shall be prevented to avoid possible spontaneous heating.

3-1.4* Frictional heating shall be minimized by the use of lubrication, inspection programs, and maintenance programs and techniques set forth by the equipment manufacturer's recommendation.

3-2 Requirements for Machinery.

3-2.1 All dust-producing machines and conveyors shall be constructed so that escape of dust is minimized.

3-2.2* 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, finishing and polishing equipment, filters, driers, dust screens, fixed storage bins, and dust collection and transport systems of all types. (*See also 2-6.1.*)

3-2.3* Ball or roller bearings, properly sealed against dust, shall be used for shafts and high-speed equipment. Where exposed bearings are used, they shall be protected as well as possible to prevent ingress of aluminum dust.

3-2.4 Internal machine clearances shall be maintained to prevent internal rubbing or jamming.

3-2.5 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 operation.

3-3 Heating of Aluminum Powder Production Buildings.

3-3.1 Heating of buildings shall be permitted by indirect hot air heating systems or by bare pipe heating systems using steam or hot water as the heat transfer medium or listed electric heaters. Indirect hot air shall be permitted if the heating unit is located in a dust-free area adjacent to the room or area where heated air is required.

3-3.2 Fans or blowers used to convey the heated air shall also be located in a dust-free location. The air supply shall be taken from outside or from a dust-free location.

3-3.3 Make-up air for building heating shall have a dew point low enough to ensure that no free moisture can condense at any point where the air is in contact with aluminum dust or powder.

3-3.4 The requirements of 3-3.1, 3-3.2, and 3-3.3 shall not apply to areas where metal is melted for purposes of atomization.

3-4 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.

3-5 Charging and Discharging Aluminum Powders.

3-5.1 All in-plant containers shall be conductive and sealed with waterproof covers while in storage or transit.

3-5.2 When charging aluminum powders to machines (or discharging from), the containers shall be positively bonded and grounded by a conducting cable from the container to a suitable ground connection and to the machine.

3-6* Containers for Transport of Aluminum Powder. Aluminum powder shall be packed into steel drums or other closed conductive containers acceptable to the U.S. Department of Transportation (DOT) or in containers specifically designed for in-plant transfer of aluminum powder. The containers shall be tightly sealed and stored with proper precautions to keep water from contacting the contents.

3-7* Wet Milling of Aluminum Powder.

3-7.1 Where aluminum is milled in the presence of a liquid which is chemically inert with respect to the metal, the milling shall be done in air in a vented mill or in an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

3-7.2 Where aluminum is slurried in tanks or processed in blenders or other similar equipment in the presence of a liquid that is chemically inert with respect to the metal, the operation shall be carried out in air or an inerting atmosphere containing sufficient oxygen to oxidize any newly exposed surfaces as they are formed.

3-7.3 The dew point of the atmospheres in 3-7.1 and 3-7.2 shall be maintained substantially below the point where condensation could occur.

3-7.4 Bearings of wet mills shall be grounded across the lubricating film by use of current collector brushes.

3-7.5 Ventilation, forced or natural, in accordance with NFPA 30, *Flammable and Combustible Liquids Code*, shall be maintained in areas where solvents are handled.

3-7.6 Solvent or slurry pumps shall be installed with proper controls to ensure that they are shut down when they run dry.

3-7.7 All electrical equipment shall be installed in accordance with appropriate provisions of NFPA 70, *National Electrical Code*.

Chapter 4 In-Plant Conveying of Aluminum Powder

4-1 Portable Containers.

4-1.1 Transfer of powders in-plant shall be done in suitable conductive containers as described in Chapter 3.

4-1.2 Powered forklift trucks shall be selected in accordance with NFPA 505, *Fire Safety Standard for Powered Industrial Trucks Including Type Designations, Areas of Use, Maintenance, and Operation*.

4-1.3 Containers approved by the U.S. Department of Transportation (DOT) for shipment of aluminum powders shall be permitted to be used.

4-1.4 All wheeled containers, hand trucks, and lift trucks shall have nonsparking, static conductive tires and wheels that have been bonded through or around the lubricating film in the bearings or shall have grounding straps.

4-2 Pneumatic Conveying.

4-2.1 Conveyor ducts shall be fabricated of nonferrous minimum-sparking metal or of nonmagnetic minimum-sparking stainless steel.

4-2.2* Ducts shall be electrically bonded and grounded to minimize accumulation of static electric charge.

4-2.3 Plastics or other nonconductive ducts or duct liners shall not be used.

4-2.4* If the conveying gas is air, the aluminum powder-to-air ratio throughout the conveying system shall be held below 50 percent of the lower flammable limit (LFL) of the aluminum powder at normal operating conditions.

4-2.4.1* Operation near or above the LFL shall be permitted if an inert gas conveying system is used. See NFPA 69, *Standard on Explosion Prevention Systems*.

4-2.4.2* The inert gas used shall be based on such gases as nitrogen, argon, helium, or flue gas, and shall have an oxygen concentration determined by test to be appropriate to the inerting gas and the particle size of the aluminum powder.

Exception: Where the product is never exposed to air, the oxygen content can be zero.

4-2.4.3 The inert gas shall have a dew point such that no free moisture can condense or accumulate at any point in the system.

4-2.4.4 The inert gas stream shall be continuously monitored for oxygen content and shall be arranged to sound an alarm if the oxygen content is not within a prescribed range.

4-2.5* Where the conveying duct is exposed to weather or moisture, it shall be moisturetight.

4-2.6 A minimum conveying velocity of 4500 ft/min (1364 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.

4-2.7 If the conveying gas is inducted into the system in a relatively warm environment and the ducts and collectors are relatively cold, the ducts and the collectors shall be either insulated or provided with heating so that the gas temperature does not fall below the dew point, causing condensation.

4-2.8* If the dust is collected in a liquid, such as in a spray tower, any liquid used shall not have a flash point below 100°F (37.8°C) and shall be nonreactive with metal dust or reactive at a controlled rate under favorable operating conditions. The liquid remaining in or on the product shall be compatible with subsequent processing requirements.

4-3 Ductwork for Conveying Systems.

4-3.1* Explosion vents, openings protected by antiflashback swing valves, or rupture diaphragms, shall be provided on ductwork. Relief shall be to a safe location outside of the building.

4-3.2 Wherever damage to other property or injury to personnel can result from the rupture of the ductwork, or where explosion relief vents cannot provide sufficient pressure relief, the ductwork shall be designed to withstand a suddenly applied internal pressure of at least 100 psig (690 kPa gauge).

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

4-4 Fan and Blower Construction and Arrangement.

4-4.1 Blades and housings of fans used to move air or inert gas in conveying ducts shall be constructed of conductive, nonsparking metal such as bronze, nonmagnetic stainless steel, or aluminum.

4-4.2 Wherever practical, the design shall not allow the transported dust or powder to pass through the fan before entering the final collector.

4-4.3 Personnel shall not be permitted within 50 ft (15.2 m) of the fan or blower while it is operating. No maintenance shall be performed on the fan until it is shut down.

Exception: If personnel approach the fan or blower while it is operating, such as for a pressure test, it shall be done under the direct supervision of competent technical personnel and with the knowledge and approval of operating management and with the flow of aluminum powder shut off.

4-4.4* Fans or blowers shall be located outside of all manufacturing buildings and so located that entrance of dust from the fan exhaust into the building shall be minimized.

4-4.5* Fans or blowers shall be equipped with ball or roller bearings. Bearings shall be equipped with suitable temperature-indicating devices and shall be arranged to sound an alarm in case of over-temperature.

4-4.6 Fans or blowers shall be electrically interlocked with powder-producing machinery so that the machines are shut down if the fan stops.

Chapter 5 Dust and Powder Collection

5-1* Collectors.

5-1.1 Dry-type collectors shall be located outside, in a safe location, and shall be provided with suitable barriers or other means for protection of personnel.

5-1.2 Collectors shall be constructed of nonferrous, minimum-sparking metal or of nonmagnetic, minimum-sparking stainless steel.

5-1.3 Ductwork shall comply with the provisions of Section 4-3.

5-1.4* The entire collection system, including the collector, shall be completely bonded and grounded to minimize accumulation of static electric charge.

5-2 Fans and Other Air-Moving Equipment.

5-2.1 Fans and other equipment for moving air shall be located so the fan is on the clean air side of the collector.

5-2.2 Fans shall be provided with ball or roller bearings.

5-3 High Temperature Warning.

5-3.1 Cyclone or other dry-type collectors shall be equipped with suitable instruments for recording the surface temperature. An over-temperature alarm or warning device shall be included and the limit setting shall be below the maximum service temperature of the filter medium or 90°F (32°C) below the ignition temperature of the powder cloud, whichever is lower.

5-3.2 Alarms and actuating equipment shall be suitable for use in Class II, Group E locations, as specified in NFPA 70, *National Electrical Code*, or shall be located in a nonhazardous location.

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

5-3.3 All such instruments shall give audible and visual alarm at normally attended locations.

5-4* Collector Filter Medium. Collector filter medium made from synthetic fabrics that accumulate high static electric charges shall not be used. Replacement filter media shall be in accordance with this criteria.

Chapter 6 Prevention of Fugitive Dust Accumulations

6-1 General.

6-1.1 This chapter shall apply to new and existing facilities.

6-1.2 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.

6-1.2.1 Final cleanup shall be permitted to be accomplished using a vacuum cleaning system designed in accordance with Section 6-2.

6-1.2.2 Compressed air blowdown shall not be permitted.

Exception: In certain areas impossible to clean otherwise, compressed air blowdown shall be done under carefully controlled conditions with all potential ignition sources prohibited in or near the area and the equipment shut down.

6-1.3 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 water will be the safest method of cleaning in the shortest exposure time.

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

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

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

6-2* Vacuum Cleaning Systems.

6-2.1 Vacuum cleaning systems shall only be used for removal of dust accumulations too small or too dispersed to be thoroughly removed by hand-brushing.

6-2.2* Vacuum cleaning systems shall be effectively grounded and bonded to minimize accumulation of static electric charge.

6-2.3 Where aluminum dust is present, the fixed vacuum cleaning system's electrical equipment shall be suitable for Class II, Group E locations.

6-2.4 Vacuum cleaner hoses shall be conductive and nozzles or fittings shall be made of conductive, nonsparking material.

6-2.5 Dust picked up by the vacuum cleaning system shall be discharged into a suitable receptacle or collector located outside the building.

6-2.6 Portable vacuum cleaners shall be used only if listed for use in the area in which they are to be used or shall be nonelectrically powered.

6-3 Cleaning Frequency.

6-3.1 Supervisors shall be alert to prevent the accumulation of excessive dust on any portions of buildings or machinery not regularly cleaned in daily operations.

6-3.2 Regular periodic cleaning of buildings and machinery, with all machinery idle and power off, shall be carried out as frequently as conditions warrant.

Chapter 7* Fire Fighting Procedures

7-1 Dry Aluminum Powders.

7-1.1 Sections 7-1 and 7-2 shall apply to new and existing facilities.

7-1.2 An incipient fire shall be ringed with a dam of dry sand, dry inert granular material, or a Class D extinguishing agent. Extreme care shall be exercised during application to avoid any disturbance of the aluminum powder, which could cause a dust cloud. The dry extinguishing material shall be stored in such a manner that it remains clean and dry.

7-1.3 The dry material shall be carefully applied with a nonsparking metal scoop or shovel or applied from an extinguisher equipped with a low-velocity nozzle.

7-1.4 Care shall be exercised to eliminate drafts by shutting off fans and machinery and by closing doors and windows.

7-1.5 Areas where dry aluminum powders are produced or handled shall not have fire extinguishers rated for Class A, B, or C fires.

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

7-2* Solvent-Wetted Powders.

7-2.1 A fire occurring while the aluminum powder is in slurry form shall be permitted to be fought using Class B extinguishing agents.

Exception: Halogenated extinguishing agents shall not be used.

7-2.2 A fire occurring in semi-wet material or filter-cake shall be fought using suitable Class B extinguishing agent.

7-2.3* Where carbon dioxide is used to extinguish fires involving solvent-wetted aluminum, the residual material shall be immediately covered with dry sand or with other suitable Class D extinguishing agent and the entire mass shall be allowed to cool until it reaches ambient temperature. When the material has cooled and it has been determined that there are no hot spots, the covered material shall be carefully removed for disposal. It shall be handled in small quantities in covered containers, preferably not more than 3 gal (11.5 L) each in 5-gal (19.2 L) containers.

7-2.4 Manual water application shall only be used on a solvent-metal powder fire as a last resort, when other methods of control have failed and the fire shows evidence of going out of control. Only low-velocity spray or fog nozzles shall be used. Extreme care shall be exercised to avoid creating a dust cloud. Once water is used, its use shall be continued until the fire is extinguished or until the area becomes untenable.

7-2.4.1 After extinguishment, the area shall be immediately cleaned of all wetted powder, paste, or slurry.

7-2.4.2 Adequate ventilation shall be provided during cleanup to avoid concentrations of hydrogen from the exothermic reaction of the aluminum with water.

7-2.4.3 Suitable drainage provisions to a safe area away from manufacturing buildings shall be provided.

7-3 Automatic Sprinkler Protection.

7-3.1 Automatic sprinkler protection shall not be permitted in areas where dry aluminum powders are produced or handled.

7-3.2 Automatic sprinkler protection shall be permitted in areas where solvents are stored or used (*see NFPA 30, Flammable and Combustible Liquids Code*); aluminum paste is produced or handled; or dry aluminum powder is stored in sealed containers.

7-3.2.1 The decision of whether or not to use automatic sprinkler protection shall be based on the need to minimize the damage to property and risk to life resulting from fires and explosions involving both wetted and dry aluminum powders.

7-3.2.2 The special hazards associated with aluminum powder in contact with water shall be considered in the selection, design, and installation of automatic sprinkler systems.

7-3.2.3 Automatic sprinkler systems shall be designed and installed in accordance with NFPA 13, *Standard for the Installation of Sprinkler Systems*.

7-3.2.4 Special attention shall be given to employee training and organizational planning to ensure safe evacuation of the sprinkler protected area, in case of fire.

7-4 Fire Fighting Organization.

7-4.1 Only trained personnel shall be permitted to engage in fire control activity. All others shall be evacuated from the area. Training shall emphasize the different types of fires anticipated and the appropriate agents and techniques to be used.

7-4.2 Fire fighting personnel shall be given regular and consistent training in the extinguishment of test fires set in a safe location away from manufacturing buildings. Training shall include all possible contingencies.

7-4.3* If professional or volunteer fire fighters are admitted onto the property in the event of a fire emergency, their activity shall be directed by the on-site ranking officer of the trained plant fire fighters.

Chapter 8 Safety Requirements

8-1* General. This chapter shall apply to new and existing facilities.

8-2 Guidelines.

8-2.1 Training programs shall be instituted to properly inform employees about the hazards involved in the manufacture of aluminum powder, paste, or granules, or the manufacture of atomized aluminum powder. As a minimum, the following areas shall be addressed:

8-2.1.1 Dust Explosion Hazards.

8-2.1.2 Control of Ignition Sources.

8-2.1.2.1* No smoking, open flames, electric or gas cutting or welding equipment, or spark-producing operations shall be permitted in the section of the building where aluminum dust is produced or handled. This type of work shall be allowed only in the areas where all machinery is shut down and the area is thoroughly cleaned and inspected to ensure the removal of all accumulations of aluminum dust. Accepted lockout/tagout procedures shall be followed for the shutdown of machinery.

8-2.1.2.2 Smoking materials, matches, and lighters shall not be carried or used by employees or visitors about the premises adjacent to or within any building in which aluminum powder is produced, handled, or loaded for shipment.

8-2.1.2.3 Propellant-actuated tools shall not be used in areas where a dust explosion can occur unless all machinery in the area is shut down and the area and machinery are properly cleaned.

8-2.1.2.4* Nonsparking tools shall be used when making repairs or adjustments on or around any machinery or apparatus where aluminum dust is present.

8-2.1.3 Housekeeping.

8-2.1.3.1 The work area shall be maintained as clean, orderly, and sanitary as working conditions allow.

8-2.1.3.2 Brooms and brushes used for cleaning shall be of a natural bristle type. Synthetic bristles shall not be used. Scoops, dustpans, etc., used for collecting sweepings shall be made of nonsparking, conductive material.

8-2.1.3.3 Dry powder dust sweepings shall not be returned to any machine for processing.

8-2.1.4 Fire Protection Equipment and Practices. (*See Chapter 7.*)

8-2.1.5 Personal Protective Equipment.

8-2.1.5.1 Outer clothing shall be clean, flame resistant, and non-static generating and shall be designed to be easily removable. Tightly woven, smooth fabrics treated with a flame-retardant chemical, and from which dust can readily be brushed, shall be used, if necessary. Woolen, silk, or synthetic fabrics that can accumulate high static electric charges shall not be used.

8-2.1.5.2 Work clothing shall have no external pockets unless covered with a flap fitted with a closure of some sort. Trousers shall not have cuffs.

8-2.1.5.3* Safety shoes shall be conductive, have no exposed metal, and shall be appropriate for the type of operation taking place.

8-2.2* Emergency procedures to be followed in case of fire or explosion shall be established. All employees shall be trained in these procedures.

8-2.3 Procedures shall be established for the recognition and control of employee exposure to air contaminants.

8-2.4 A thorough inspection of the operating area shall take place on an "as needed" basis to help ensure that the equipment is in good condition and that proper work practices are being followed. This inspection shall be conducted at least quarterly, but shall be permitted to be done more often.

8-2.4.1 It shall be conducted by a person(s) knowledgeable in the proper practices, who shall record the findings and recommendations.

8-2.4.2 Regular and periodic maintenance checks and calibration on equipment critical to employee safety and plant operation shall be performed.

8-2.5 Deluge showers shall be installed at strategic locations immediately outside critical working areas to quickly douse clothing fires.

8-2.6 Fire Blankets. Fire blankets shall be provided throughout the plant area.

Chapter 9 Referenced Publications

9-1 The following documents or portions thereof are referenced within this standard 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.

9-1.1 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 30, *Flammable and Combustible Liquids Code*, 1993 edition.

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

NFPA 496, *Standard for Purged and Pressurized Enclosures for Electrical Equipment*, 1993 edition.

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

NFPA 780, *Lightning Protection Code*, 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-1-1.1 Certain "nondusting" grades of aluminum flake powder are being produced. Although they exhibit less tendency to be dispersed into a dust cloud, the same precautions described in this standard should be observed.

A-1-5 Combustible Aluminum Dust. Any time a combustible dust is processed or handled, a potential for explosion exists. The degree of explosion hazard will vary depending on the type of combustible dust and processing methods used.

A dust explosion has three requirements, all of which must be met:

(a) The dust must be combustible.

(b) The dust particles must form a cloud at or exceeding the lower flammable limit.

(c) A source of ignition must be present.

Evaluation of a combustible dust explosion hazard and the prevention techniques employed should be determined by means of actual test data. All combustible dusts that may produce a dust explosion should be tested so as to determine the following data:

(a) Particle size distribution.

(b) Moisture content as received and dried.

(c) Minimum dust concentration to ignite.

(d) Minimum energy required for ignition (joules).

(e) Maximum rate of pressure rise at various concentrations.

(f) Layer ignition temperature.

(g) Maximum explosion pressure, at optimum concentration.

Optional Testing.

(a) Dust cloud ignition temperature.

(b) Maximum permissible oxygen content to prevent ignition.

(c) Electrical resistivity measurement.

A-2-3.7 For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

A-2-5.1 For information on deflagration venting, see NFPA 68, *Guide for Venting of Deflagrations.*

A-2-6.1 For information on static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A-3-1.4 Temperature-sensing elements connected to alarms or machine stop switches may be employed for locations where overheating of bearings or other elements may be anticipated.

A-3-2.2 See NFPA 77, *Recommended Practice on Static Electricity*, for information on the subject.

A-3-2.3 Journal bearings should not be used because of the difficulty of maintaining proper lubrication to prevent overheating. Outboard bearings are used where practical because it is easier to check for overheating. In those instances where dust tends to penetrate bearings a continuous flow of inert gas ($1\frac{1}{2}$ to 5 percent oxygen) can be employed to pressurize the bearings and seals.

A-3-6 Open bin storage is not desirable. Storage bins can be sealed and they can be purged with inert gas prior to filling. Once filled, the bins can be maintained inert by a suitable gas as detailed in 4-2.4.2.

A-3-7 When aluminum is milled in the presence of a liquid that is chemically inert with respect to the metal, the air-dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air, any unoxidized surfaces produced during milling will react and may generate enough heat to cause ignition. To prevent this, it is imperative that a controlled amount of oxygen be present in the milling operation and in slurries ahead of filters and blenders, so that new surfaces are oxidized as they are formed. The addition of a milling agent, such as stearic acid, does not eliminate the need for this added oxygen.

A-4-2.2 See NFPA 77, *Recommended Practice on Static Electricity.*

A-4-2.4 These minimum explosive concentrations are published in U.S. Bureau of Mines, RI 6516, "*Explosibility of Metal Powders.*" Although the aluminum powder-air suspension may be held below 50 percent of the LFL in the conveying system, the suspension will necessarily pass through the flammable range in the collector at the end of the system unless the dust is collected in liquid, such as in a spray tower. Also, the powder in the conveying line from the atomizer to the collector will, of necessity, approach the lower flammable limit.

A-4-2.4.1 Aluminum and aluminum alloy powders are produced by various means. These processes, as well as certain finishing and transporting operations, tend to expose a continuously increasing area of new metal surface. Most metals immediately undergo a surface reaction with available atmospheric oxygen which forms a protective coating of metal oxide that serves as an impervious layer to inhibit further oxidation. This reaction is exothermic. If a fine or thin lightweight particle having a large surface area of "new" metal is suddenly exposed to the atmosphere, sufficient heat will be generated to raise its temperature to the ignition point.

Completely inert gas generally cannot be used as an inerting medium since the aluminum powder would eventually, at some point in the process, be exposed to the atmosphere, at which time the unreacted surfaces would be oxidized; enough heat would be produced to initiate either a fire or an explosion. To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces is provided by regulating the oxygen concentration in the inert gas. The mixture serves to control the rate of oxidation, while materially reducing the fire and explosion hazard.

A completely inert gas can be used if the powder so produced will not be exposed to air.

A-4-2.4.2 Oxygen limits of 3 to 5 percent have been maintained in aluminum powder systems using a controlled flue gas. Other limits are applicable where other inert gases are used. Refer to U.S. Bureau of Mines, RI 3722, "*Inflammability and Explosibility of Metal Powders.*"

A-4-2.5 Any moisture entering the system can react with the aluminum powder, generating heat and hydrogen. Hydrogen is extremely flammable and very easy to ignite. It must not be trapped in nonventilated areas of buildings, equipment, or enclosures.

A-4-2.8 Such wet collection is not always possible or desirable.

A-4-3.1 For information on explosion vents, see NFPA 68, *Guide for Venting of Deflagrations.*

A-4-4.4 Ultimately, all fans or blowers in dust collector systems accumulate sufficient powder to become a potential explosion hazard.

A-4-4.5 Fans or blowers may also be provided with vibration-indicating devices, arranged to sound an alarm or to provide shutdown, or both, in the event of blade or rotor imbalance, or bearing or drive problems.

A-5-1 A high-efficiency cyclone-type collector presents less hazard than a bag- or media-type collector and, except for extremely fine powders, will usually operate with fairly high collection efficiency. Where cyclones are used, the exhaust fan discharges to atmosphere away from other operations. It should be recognized that there will be some instances in which a centrifugal-type collector may be followed by a fabric or bag- or media-type collector or by a scrubber-type collector where particulate emissions are kept at a low level. The hazards of each collector should be recognized and protected against. In each instance, the fan will be the last element downstream in the system. Because of the extreme hazard involved with a bag- or media-type collector, consideration should be given to a multiple-series cyclone with a liquid final stage.

Industry experience has clearly demonstrated that an eventual explosion can be expected where a bag- or media-type collector is used to collect aluminum fines. Seldom, if ever, can the source of ignition be positively identified. In those unusual instances when it becomes necessary to collect very small fines for a specific commercial product, it is customary for the producer to employ a bag- or media-type collector. With the knowledge that strong explosive potential is present, the producer will locate the bag- or media-type collector a safe distance from buildings and personnel.

If a bag- or media-type collector is used, the shaking system or dust removal system can be such as to minimize sparking due to frictional contact or impact. Pneumatic or pulse-type shaking is more desirable because no mechanical moving parts are involved in the dusty atmosphere. If the bags are provided with grounding wires, they can be positively grounded through a low-resistance path to ground. Where bags are used, it is customary that the baghouse be protected by an alarm to indicate excessive pressure drop across the bags. An excess air temperature alarm is also frequently employed. A bag- or media-type collector is customarily located at least 50 ft (15.2 m) from any other building or operation. It is not customary to permit personnel to be within 50 ft (15.2 m) of the collector during operation or when shaking bags. Explosion vents are usually built into the system, as described in NFPA 68, *Guide for Venting of Deflagrations.* Care is customarily exercised in locating the vents because of the possibility of blast damage to personnel or adjacent structures.

A-5-1.4 For information on precautions for static electricity, see NFPA 77, *Recommended Practice on Static Electricity.*

A-5-4 Some collector bags or other types of media or screens have fine, noninsulated wire enmeshed into or woven with the cloth or otherwise fastened to it. These are always securely grounded. It should be pointed out that this is not a positive guarantee of static charge removal because there is no dependable force to cause the charges to move across the nonconducting area of the fabric to the grounded wires. Often, a substantial potential difference can be measured. Also, it is possible that a wire in the cloth may break in such a way that it is no longer grounded. Such a wire serves as a capacitor and may store a static charge.

A-6-2 Permanently installed vacuum cleaning systems provide the maximum safety because the dust collecting device and the exhaust blower can be located in a safe location outside the dust-producing area. The dust collector should be located outside the building, preferably more than 50 ft (15.2 m) away. If the collector is located closer than 50 ft (15.2 m), it is usually surrounded by a strong steel shield, cylindrical in shape and open at the top, or closed with a light, unfastened cover. The shield is closed at the bottom and designed to withstand a blast pressure of 200 psig (1380 kPa gauge). Such a protective barricade will direct an explosion harmlessly upward and will protect both property and personnel. All suction lines should be provided with explosion vents and anti-flashback valves.

A-6-2.2 See NFPA 77, *Recommended Practice on Static Electricity.*

A-7 Since it is almost impossible to extinguish a massive fire in dry aluminum powder, the fire problem resolves itself into the control of fires in the incipient stage. The requirements of Section 7-1 should be followed if the fire is to be controlled quickly. This is especially true with regard to the application of the extinguishing material, as even a minor dust cloud can explode violently.

A properly ringed fire will develop a hard crust of metal oxide, which will ultimately exclude enough oxygen to cause self-extinguishment. It is customary practice, after dispensing the extinguishing material, to leave the area, closing all doors leading to the area and sealing them with sand. The area should not be re-entered until combustion has stopped and the material has cooled.

A-7-2 Milling of aluminum with combustible solvents is practiced in the manufacture of aluminum flake used in

pigments and powders. The material is handled as a slurry during processing. Some of the product is marketed as a paste; other portions are filtered, dried, sometimes polished, and sold as dry flake powder. The solvents employed are generally moderately high flash-point naphthas. A fire in an aluminum powder slurry is primarily a solvent fire and can be fought using Class B extinguishing agents, except for halogenated extinguishing agents.

Major producers usually employ fixed extinguishing systems of carbon dioxide or foam in this area. Some Class B portable extinguishers are provided also. Obviously, judgment should be used in determining whether Class B extinguishing agents can be safely used. If the extinguishing agent is carefully applied, it will be very evident if it accelerates the fire. If it does, its use should be discontinued and a dry inert granular material used. A fire in filter cake, a solvent-wetted but semi-dry material containing aluminum, may be a solvent fire or it may at some point exhibit the characteristic of a powder fire, at which time it should be treated as such. If the aluminum metal has ignited, it may continue to burn under a crust without flames.

A-7-2.3 Reignition may occur due to high localized heat or spontaneous heating. To avoid reignition, the residual material should be immediately smothered.

A-7-4.3 It is recommended that a practice fire drill be conducted once each year to familiarize local fire department personnel with the proper methods of fighting Class D fires.

A-8-1 Employees' health and safety in operations depend on the recognition of actual or potential hazards, controlling or eliminating these hazards, and training employees to work safely.

A-8-2.1.2.1 Attention is called to the hazardous conditions that may exist both inside and outside the plant if cutting torches are used to dismantle dust collectors or powder-producing machinery before all dust accumulations have been removed.

It is a commonly recognized practice that operators of cutting or welding torches be required to obtain a written permit from the safety or fire protection officer of the plant before using their equipment under any condition around aluminum powder plants.

A-8-2.1.2.4 Under certain circumstances, such as impact with rusted iron or steel, aluminum cannot safely be considered to be nonsparking since a minor thermite reaction can be initiated. For details, refer to "Aluminum and the Gas Ignition Risk," by H. S. Eisner and "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction." (*See Appendix C.*)

A-8-2.1.5.3 Safety shoes meeting the following guidelines should be worn by all operating personnel except those persons who are required to work on electrical circuits or equipment.

(a) Soles should be resistant to embedding particles and to petroleum solvents, if used.

(b) Soles and heels should be attached by sewing or pegging.

(c) Nails, metal cleats, or metal plates should not be used.

(d) Safety toe caps should be completely covered with a scuff-resistant material.

(e) Soles and heels should be static conductive.

A-8-2.2 Employee Training.

(a) All employees should be carefully and thoroughly instructed by their supervisors regarding the hazards of their working environment and their behavior and procedures in case of fire or explosion.

(b) All employees should be shown the location of electrical switches and alarms, first-aid equipment, safety equipment, and fire extinguishing equipment.

(c) All employees should be taught the permissible methods for fighting incipient fires in pastes and for isolating aluminum fires.

(d) The hazards involved in causing dust clouds and the danger of applying liquids onto an incipient fire should be explained.

(e) Strict discipline and scrupulous housekeeping should be maintained at all times.

(f) Attention should be given to employee training and organizational planning to ensure safe and proper evacuation of the area.

Appendix B Electrically Conductive Floors

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

B-1 General.

B-1.1 Electrically conductive flooring is often employed in aluminum 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. Careful examination of the details of this standard will disclose the logic of the use of conductive flooring materials.

B-1.2 The surface of a conductive floor will provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor, thus preventing the accumulation of dangerous electrostatic charges.

B-1.3 The maximum resistance of a conductive floor is usually less than 1,000,000 ohms, as measured between two electrodes placed three feet 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 are checked at regular intervals, usually once each month.

B-2 Testing for Minimum and Maximum Resistance. The following equipment and procedures are accepted practice.

B-2.1 Each electrode will weigh 5 lbs (2.27 kg) and will have a dry, flat, circular contact area 2.5 in. (6.4 cm) in diameter. The electrode will consist of a surface of aluminum foil 0.0005 in. (0.013 mm) to 0.001 in. (0.025 mm)

thick, backed by a layer of rubber 0.25 in. (6.35 mm) thick and measuring 40 to 60 durometer hardness, as determined by a Shore Type A Durometer or equivalent, per ASTM D2240, *Standard Test Method for Rubber Property — Durometer Hardness*.

B-2.2 Resistance may 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 to 10.0 m amp.

B-2.3 Measurements may be made at five or more locations in each room and the results averaged.

B-2.4 For compliance with the maximum resistance limit, the average of all measurements should be less than 1,000,000 ohms.

B-2.5 For compliance with the minimum resistance limit, no individual measurement should be less than 10,000 ohms and the average of not less than five measurements should be greater than 25,000 ohms.

B-2.6 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. If resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five minutes can be considered the measured value.

Appendix C Referenced Publications

C-1 The following documents or portions thereof are referenced within this standard 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.

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

NFPA 30, *Flammable and Combustible Liquids Code*, 1993 edition.

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

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

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

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

NFPA 497A, *Recommended Practice for Classification of Class I Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas*, 1992 edition.

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

NFPA 780, *Lightning Protection Code*, 1992 edition.

C-1.2 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.

C-1.3 U.S. Bureau of Mines Publications. U.S. Bureau of Mines, Cochrans Mill Road, Pittsburgh, PA, 15236-0070.

RI 3722, "*Inflammability and Explosibility of Metal Powders*," I. Hartmann, J. Nagy, and H. R. Brown, 1943.

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

C-1.4 Other Publications.

Eisner, H. S., "Aluminum and the Gas Ignition Risk," *The Engineer*, London, February 17, 1967.

Gibson et. al., "Fire Hazards in Chemical Plants from Friction Sparks Involving the Thermite Reaction," *Industrial Chemists Engineering Symposium Series*, No. 25, London, 1968.

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