NFPA No.

651

USAS Z12.11

DUST EXPLOSION PREVENTION

ALUMINUM POWDER 1967

A USA Standard

Fifty Cents

NATIONAL FIRE PROTECTION ASSOCIATION
International
60 Batterymarch Street, Boston, Mass. 02110

2M-6-67-FP
Printed in U.S.A.

National Fire Protection Association
International

Official NFPA Definitions

Adopted Jan. 23, 1964. Where variances to these definitions are found, efforts to eliminate such conflicts are in process.

SHALL is intended to indicate requirements.

SHOULD is intended to indicate recommendations or that which is advised but not required.

APPROVED means acceptable to the authority having jurisdiction. 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 nationally recognized testing laboratories,* i.e., laboratories qualified and equipped to conduct the necessary tests, in a position to determine compliance with appropriate standards for the current production of listed items, and the satisfactory performance of such equipment or materials in actual usage.

*Among the laboratories nationally recognized by the authorities having jurisdiction in the United States and Canada are the Underwriters' Laboratories, Inc., the Factory Mutual Engineering Corporation, the American Gas Association Laboratories, the Underwriters' Laboratories of Canada, the Canadian Standards Association Testing Laboratories, and the Canadian Gas Association Approvals Division, and Yacht Safety Bureau.

LISTED: Equipment or materials included in a list published by a nationally recognized testing laboratory that maintains periodic inspection of production of listed equipment or materials, and whose listing states either that the equipment or material meets nationally recognized standards or has been tested and found suitable for use in a specified manner.

LABELED: Equipment or materials to which has been attached a label of a nationally recognized testing laboratory that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling is indicated compliance with nationally recognized standards or the conduct of tests to determine suitable usage in a specified manner.

AUTHORITY HAVING JURISDICTION: The organization, office or individual responsible for "approving" equipment, an installation, or a procedure.

Units of Measurements

Units of measurements used here are U. S. standard. 1 U. S. gallon = 0.83 Imperial gallons = 3.785 liters. One foot = 0.3048 meters. One inch = 25.40 millimeters. One pound per square inch = 0.06805 atmospheres = 2.307 feet of water. One pound = 453.6 grams.

Code for the Prevention of Dust Explosions in the Manufacture of Aluminum Powder

NFPA No. 651 — 1967
USAS Z12.11-1967 UDC 628.511:614.83/.84

1967 Edition of No. 651

The 1967 edition of the Code for the Prevention of Dust Explosions in the Manufacture of Aluminum Powder incorporates changes prepared by the Sectional Committee on Metal Dusts and adopted at the 1967 Annual Meeting of the National Fire Protection Association on recommendation of the Committee on Dust Explosion Hazards. It supersedes the 1963 edition. Amendments in 1967 include a complete revision of Chapter 3, Conveying Powder; complete revision of Chapter 10, Fire Fighting Methods; and addition of a new Chapter 9, Wet Milling of Aluminum Powder.

This 1967 edition of NFPA No. 651 was approved as a USA Standard by the United States of America Standards Institute on November 13, 1967.

Origin and Development of No. 651

This Code 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, and 1967.

NFPA Committee on Dust Explosion Hazards

C. G. Gibson, *Chairman,*
Ontario Department of Labour, 8 York St., Toronto 1, Ont., Canada (rep. Canadian Assn. of Administrators of Labour Legislation)

R. W. Andrews, Jr., American Society of Mechanical Engineers.
David W. Bixby, The Sulphur Institute.
C. M. Blaesi, NFPA Committee on Blower Systems.
J. J. Burke, American Society of Heating, Refrigerating & Air Conditioning Engineers, Inc.
Dean M. Clark, Grain Elevator and Processing Superintendents.
D. P. Congdon, Factory Insurance Assn.
R. E. Dufour, Underwriters' Laboratories, Inc.
Douglas L. Hail, Millers' National Federation.
S. F. Henderson, National Electrical Manufacturers Assn.
J. A. Houghton, American Foundrymen's Society.
David H. Hunt, The Spencer Turbine Co.
Guy Isenberg, Manufacturing Chemists' Assn.
George L. Kitchen, Terminal Elevator Grain Merchants' Assn.
G. C. Koth, Factory Mutual Engineering Corporation.
J. R. McCann, National Safety Council.
Reynar Meadowcroft, Corn Industries Foundation.
Dr. E. G. Meiter, American Industrial Hygiene Assn.
John Nagy, U. S. Dept. of the Interior.
Don O. Noel, Metal Powder Producers Assn. of the Metal Powder Industries Federation.
John P. O'Neill, U. S. Department of Labor.
Thomas A. Oravecz, International Assn. of Governmental Labor Officials.
J. A. Peloubet, The Dow Metal Products Co.
Frank E. Rademacher, Factory Insurance Assn.
J. M. Robinson, American Insurance Assn.
W. A. Roessler, Assn. of Mill & Elevator Mutual Ins. Cos.
Arthur C. Schrier, National Confectioners' Assn.
T. T. Singer, Western Actuarial Bureau.
George H. Steel, American Society of Safety Engineers.
J. Karel Sundermeyer, Society of the Plastics Industry, Inc.
Paul J. Turner, Great Northern Railway.
H. L. Walker, Edison Electric Institute.
James B. Walker, Jr., American Boiler Mfrs. Assn.
J. A. Wood, National Automatic Sprinkler & Fire Control Assn.
G. M. Woods, Jr., Kemper Insurance Company.

Alternates.

G. Walker Daubenspeck, U. S. Department of Labor. (Alternate to John P. O'Neill.)
John F. Hennessey, National Confectioners' Assn. (Alternate to Arthur C. Schrier.)
J. M. Jensen, Corn Industries Foundation. (Alternate to Reynar Meadowcroft.)
Frank Jun, Millers' National Federation. (Alternate to Douglas L. Hail.)
Harry G. Lacey, International Assn. of Governmental Labor Officials. (Alternate to Thomas A. Oravecz.)
Gordon A. Olson, Edison Electric Institute. (Alternate to H. L. Walker.)
G. D. Perkins, Association of Mill & Elevator Mutual Insurance Cos. (Alternate to W. A. Roessler.)
R. F. Schwab, Factory Insurance Assn. (Alternate to D. P. Congdon and Frank E. Rademacher.)
L. S. Shook, Western Actuarial Bureau. (Alternate to T. T. Singer.)
Max Spencer, Grain Elevator & Processing Superintendents. (Alternate to Dean M. Clark.)
E. J. Williams, American Society of Heating, Refrigerating & Air Conditioning Engineers, Inc. (Alternate to J. J. Burke.)

SCOPE: The prevention of dust explosions in connection with processes and industries producing combustible or explosive dusts, including measures for the prevention of ignition, restriction of potential damage by proper construction and arrangement of buildings, restriction of the production and escape of dust through the control of dust-producing processes and equipment, extinguishing methods, and related features. Fire prevention and extinguishing are included, since dust explosions may result from fire.

STANDARD FOR THE PREVENTION OF DUST EXPLOSIONS IN THE MANUFACTURE OF ALUMINUM POWDER

NFPA No. 651 — 1967

Contents

CHAPTER 1. INTRODUCTION.

11. The objective of this Standard is to reduce the hazards of ignition and explosions in the manufacture of aluminum flake powder, or paste and atomized aluminum granular particles, and/or the dust of any aluminum alloy that is explosive in an environmental gas, as determined by test.

12. Where the Standard has reference to plant location or construction, or the installation of radically new types of equipment, the specifications are not retroactive in application.

13. All new installations should be under the supervision of engineers qualified by experience in the design, construction and operation of equipment for the purpose.

14. This Standard is not intended to apply to situations where waste dust is produced by operations such as grinding, buffing and polishing of aluminum castings. Prevention of fires and explosions in industries where aluminum and aluminum alloys are subject to processing or finishing operations in which a fine metallic dust or powder is liberated is covered in NFPA No. 65, Code for the Processing and Finishing of Aluminum.

15. Definitions. In this Standard the following words are used as defined below:

SHALL is intended to indicate requirements.

SHOULD is intended to indicate recommendations, or that which is advised but not required.

APPROVED refers to approval by the authority having jurisdiction in the enforcement of standards.

CHAPTER 2. LOCATION AND BUILDINGS OF ALUMINUM POWDER-MAKING PLANT.

21. Location of the Plant.

211. The plant should be located on a tract of land large enough so that the buildings in which the powder is manfactured shall be at least 300 feet distant from occupied structures such as public buildings, dwellings, stores or manufacturing establishments other than those which are a part of the powder manufacturer's plant. The premises in which are located the powder-making buildings should be surrounded by high strong fencing with suitable entrance gates under charge of a guard to the property and should be well floodlighted at night for safety.

22. Location of Operations.

221. Different operations in the manufacture of aluminum powder should be located in separate buildings further subdivided into as many small units as practicable by substantial brick or reinforced concrete division walls without openings. Separate buildings (other than the small units of a major process section) should preferably be separated by not less than 50 feet of space and in no case shall they be less than 25 feet apart, unless barricades, similar to those used in explosives manufacturing plants, are built between the buildings. Where two buildings are less than 50 feet apart, only one of those shall have windows or doors in the wall facing the other building.

222. For new construction, in addition to designing to fulfill minimum statutory requirements, the insurance carrier involved or one of the major insurance engineering organizations should be consulted for counsel regarding specific installations.

23. Electric or Steam Power Generators.

231. Electric or steam power generators shall be in a separate building or buildings which should be at least 100 feet from the dust-making building.

24. Building Construction.

241. All buildings used for the manufacture, packing or loading for shipment of aluminum powder shall conform with the following requirements:

a. CHARACTER OF BUILDINGS: They shall, where practical, be of one-story type, with no basements, and constructed of noncombustible materials throughout, and the buildings shall be designed so that every internal surface is readily accessible to facilitate cleaning. In all building walls of rooms where dust may be produced, which are not of monolithic construction, all masonry joints shall be thoroughly slushed with mortar and troweled smooth so as to leave no interior or exterior voids for the infiltration and accumulation of aluminum powder. Where elevated floors, platforms or balconies are required, as possibly for tanks or collectors or for other process reasons, the same principles shall apply. Floor covering and railings shall be of minimum sparking metal construction and all internal metal structures shall be adequately grounded. Suitable emergency exits shall be provided from all areas, including from balconies.

b. CONSTRUCTION WITH REFERENCE TO POSITION OF BUILDINGS: Where two buildings are less than 50 feet apart, one of the facing walls shall be blast resistant — either reinforced concrete or brick construction without openings (preferably reinforced concrete); the other facing wall may be of "daylight type" construction.

c. COMMUNICATIONS BETWEEN BUILDINGS: Buildings separated by not less than 50 feet of space (or small units of one major process section) may communicate through enclosed passageways of noncombustible construction, provided that such enclosed passageways from production or storage areas are specially designed for the release of internal pressures and all openings to such passageways are protected by self-closing fire doors approved for the protection of openings in fire division walls. An exit door for escape from enclosed passageways to outdoors should be provided (see Section 241d following).

d. FRAMES OF DOORS AND WINDOWS should be of metal; the doors shall be approved self-closing fire doors. There should be adequate window areas both for light and in case of an explosion to afford relief of pressure by automatically opening; windows which may be opened should be hinged at the top, open outward and, if fastened with catches, these should release on moderate pressure from the inside. See the Guide for Explosion Venting, NFPA No. 68, for suggested vent ratios in specified room volumes. Each room should have at least two widely separated exits to corridors or to the outside. All exit doors to the outside for escape purposes shall be of the emergency type, opening outward with a pressure bar latch. See 5-216, Panic Hardware, of the Code for Safety to Life from Fire in Buildings and Structures, NFPA No. 101.

e. FLOORS OF BUILDINGS: Hard surfaced nonslip floors should be installed in a manner that avoids joints which might catch and collect dust.

The use of electrically conducting floor material is recommended although it is recognized that it is difficult to maintain conductance over a period of time using materials now available. Careful examination of the details of this Standard will disclose the logic of the employment of conducting floor materials.

The surface of a conductive floor should provide a path of moderate electrical conductivity between all persons and portable equipment making contact with the floor to prevent the accumulation of dangerous electrostatic charges. Fixed machinery and equipment shall be individually grounded as indicated in the appropriate paragraph of this Standard.

The maximum resistance of the conductive floor should be less than 1,000,000 ohms, as measured between two electrodes placed 3 feet apart at any points on the floor.

The minimum resistance of the conductive floor should be more than 25,000 ohms, as measured between a ground connection and an electrode placed at any location on the floor. This minimum resistance value is recommended to provide protection for personnel against the hazard of electrical shocks.

Resistance values should be checked at regular intervals. The following equipment and methods are recommended:

(1) Each electrode shall weigh 5 pounds and shall have a dry, flat, circular contact area 2½ inches in diameter, which shall comprise a surface of aluminum foil 0.0005 to 0.001 inches thick, backed by a layer of rubber ¼ inch thick and measuring 40 to 60 durometer hardness as determined by a Shore Type A durometer or equivalent.*

(2) Resistance shall be measured with a suitably calibrated ohmmeter, which shall operate on a nominal open-circuit output voltage of 500 volts DC and a short circuit current of 2.5 to 10 milliamperes (showing units of resistance).

(3) Measurements** shall be made at five or more locations in each room and the results averaged.

(a) For compliance with *maximum* resistance the average shall be less than 1,000,000 ohms, and

*American Society for Testing Materials Tentative Method of Test for Indentation of Rubber by Means of a Durometer, ASTM Designation D-676-59T, obtainable from ASTM, 1916 Race St., Philadelphia, Pa. 19103.

**NOTE: If the resistance changes appreciably with time during a measurement, the value observed after the voltage has been applied for about five seconds shall be considered to be the measured value.

(b) For compliance with *minimum* resistance no location shall have a resistance less than 10,000 ohms and the average of not less than five locations shall be greater than 25,000 ohms. Where resistance to ground is measured, two measurements shall be made at each location, with the test leads interchanged at the instrument between measurements, with the average to be taken as the resistance to ground at that location. All readings may be taken with the electrode or electrodes more than 3 feet from any ground connection or grounded object resting on the floor.

In certain manufacturing areas any use of water must be avoided. Where it is possible to use water for washing down without danger of leaving damp powder in dust-catching joints and without danger of water lodging in equipment, this method of cleaning may be used. This method of cleaning shall be confined to floors, walls and structural elements that can be washed down completely, leaving no powder residue and without water coming in contact with any powder processing equipment. In such areas the floor shall be pitched to water drains in the floor leading to an isolated area from which the collected powder can be transferred to a safe disposal location. Sanitary or sewage disposal systems shall not be used for this purpose.

f. ROOFS OF BUILDINGS in which there are dust-making operations shall be supported on girders so designed as to minimize the area of surfaces on which dust may collect. Where these surfaces are unavoidably present, and on other more or less horizontal places, such as wide girder flanges and window ledges, they shall be covered by a smooth, steeply sloping concrete or plaster filling having a minimum angle of 55 degrees with the horizontal. The roof covering shall be as light as practicable, but fire resistant, and shall be so arranged that it will be easily blown off by an internal explosion. Any sheet metal used in the roof covering shall be well cemented to prevent leakage and be well painted with aluminum paint, or else shall be galvanized and well maintained to prevent corrosion, which might cause leakage.

g. GROUNDING AND LIGHTNING PROTECTION: All steel work should be well grounded to a suitable ground outside the building in accordance with the Lightning Protection Code, NFPA No. 78. Lightning rods should be provided for all boiler house stacks or chimneys and high points on buildings. The power lines should be adequately protected against lightning. A lightning arrestor system should be provided around or within the building area, of such a capacity as to fully protect all buildings in that area from lightning.

CHAPTER 3. CONVEYING POWDER.

31. Construction and Grounding of Dust-Making Machines.

311. All dust-making machines and conveyors shall be so constructed as to minimize the escape of dust into the rooms in which they are located. All parts of the machinery and conveyors shall be thoroughly bonded and grounded to minimize static discharges (see Chapter 5, Control of Static Electricity).

32. Conveying of Aluminum Powder.

321. MOVABLE CONTAINERS: Movable containers for transporting powder shall be constructed throughout of nonferrous, minimum sparking material or nonmagnetic, minimum sparking stainless steel. These containers shall be provided with wheels or casters with nonsparking conductive tires. If rails are used for placing containers, locking type swivel casters should be provided to eliminate heat of friction at the time container's motion is reversed. If the floor is a conducting material and it is desired to establish an electrical ground through the wheels or casters, the wheels or casters may be made of aluminum, bronze or other minimum sparking conductive materials. To obtain positive grounding, it is necessary to provide positive bonding either through or around the lubricating film in the bearings. When charging or discharging the container, the container shall be positively grounded by a conducting cable from the container to a suitable ground connection. When these containers have to be transported in the open, they shall be protected from the weather by minimum sparking metallic covers. Covers are also advisable for all storage conditions.

322. PNEUMATIC CONVEYING: Pneumatic conveying is a common method of transferring the dust from place to place in a building or to an adjacent building. Conveyor ducts shall be fabricated from nonferrous, minimum sparking metal or nonmagnetic minimum sparking stainless steel. The ducts shall be electrically bonded and grounded. Plastic or other nonconductive liners shall not be used. Preferably an inert gas should be used instead of air in such a system wherever the concentration of powder will possibly come within the explosive range. The inert gas should be a nitrogen type with an oxygen content of 3 per cent to 5 per cent. It should contain no carbon monoxide and must have a dew point sufficiently low as to insure that no free moisture can condense out and accumulate at any point in the system.

323. INERT ATMOSPHERE: Aluminum and aluminum alloy powders are produced by various mechanical means of particle size degradation. These processes, as well as certain finishing and transporting operations, have a tendency to expose a continuously increasing area of new metal surface. Aluminum, and in fact most metals, immediately experience a surface reaction with available atmospheric oxygen to form a protective oxide coating which then serves as an impervious layer to inhibit further oxidation. This reaction is exothermic, producing sensible heat. If a fine or thin lightweight particle having a large area of new surface is suddenly exposed to the atmosphere, enough heat will be generated to raise its temperature to the ignition point. Completely inert gas should not be used as an envelope to promote operational safety or for transport of aluminum powder in a pneumatic or fluidized transfer device. This would be a very unsafe practice because somewhere in the process of manufacture, packaging, or ultimate use the powder will eventually be exposed to the atmosphere where the unreacted surfaces will react suddenly with available oxygen to produce enough heat to cause either a fire or an explosion. To provide maximum safety, a means for the controlled oxidation of newly exposed surfaces should be provided as soon as they are exposed. Tests conducted by the U. S. Bureau of Mines and others have disclosed that an inert gas as described in Section 322 is effective for this purpose. This mixture serves to control the rate of oxidation and at the same time provides an environment which materially reduces the fire and explosion hazard.

324. AIR CONVEYING: If the conveying gas is air, the aluminum dust-air ratio throughout the conveying system shall be held below the minimum explosive concentration of aluminum as determined by the Bureau of Mines and reported in Bureau of Mines Report of Investigations 6516, "Explosibility of Metal Powders." Although the aluminum dust-air suspension may be held below an explosive concentration in the conveying system, the suspension necessarily will pass through the explosive range in the collector at the end of the conveying system unless the dust is collected in a liquid — such as a spray tower. Any such liquid shall be nonflammable, nonreactive with the aluminum dust or react at a controllable minimal rate and the liquid in the product should be compatible with subsequent processing requirements. In an air conveying system, any dry collector must be considered as an explosion hazard, containing a dust-air mixture in the explosive range, and should be constructed of nonferrous, nonsparking material or nonmagnetic, nonsparking stainless steel. The entire system and particularly the collector shall be thoroughly and completely bonded

and grounded and the entire ground system checked with an ohmeter to show less than 5 ohms (2 ohms, if possible) resistance (see Chapter 5, Control of Static Electricity). A high efficiency cyclone-type collector presents less hazard than a bag-type collector and except for extremely fine powders will usually operate with acceptable dust losses. Unless such losses are prohibitive, the cyclone type collector should be used and, in this case, the exhaust fan shall discharge to atmosphere away from other operations. If a bag type collector is used, the shaking system or dust discharge system shall either be of the pneumatic type with no moving parts, or shall be of nonferrous, nonsparking components or nonmagnetic, nonsparking stainless steel and the bags shall be positively grounded to the baghouse framework (see grounding systems for bags in Chapter 5, Article 51). If bags are used, an alarm should be added to be actuated by a build-up in pressure across the bags, beyond prescribed limits. The collector, in all cases, shall be located at least 50 feet from any other building or operation, shall be isolated by a fence or other barrier and personnel shall not be permitted within 50 feet of the collector during operation or shaking (see Chapter 2, Article 22). Blowout patches or explosion vents should be built into the system in accordance with recommendations in the Explosion Venting Guide, NFPA No. 68.

a. Where the conveying duct is exposed to weather or moisture, it shall be moisturetight, as any moisture entering the system can react with the aluminum dust, generating heat and serving as a potential source of ignition. (Sufficient velocity 5,500 feet per minute minimum) shall be provided throughout the conveying system to prevent accumulation of dust at any point and to pick up any powder that might drop out during an unscheduled system stoppage. If the conveying gas is inducted into the system in a relatively warm environment and the duct work and collectors then are subjected to a relatively cold environment, at such cold locations, temperatures may drop below the dew point of the conveying gas. In such cases, the duct and collector shall be suitably insulated to maintain the temperature of the conveying gas above the dew point to prevent moisture from condensing inside the system.

33. Relief Vents of Conveyor Ducts.

331. Wherever, in the ducts, it is practicable to have relief vents of sufficient area with antiflash-back swing valves extending to the outside of the building, these shall be provided. Care shall be taken to limit the inertia of swing valves to the minimum required.

332. WORKING PRESSURE STRENGTH OF DUCTS: Wherever damage may result from the rupture of a duct, in case the relief vent does not offer sufficient relief, the duct should be designed for a working pressure of at least 100 pounds per square inch. Where so located that no damage will result from its bursting, it should be of the lightest construction possible.

34. Fan Construction and Arrangements.

341. Blades and housing of fans that are used to move the air or inert gas in conveying ducts should be constructed of nonsparking material such as bronze or aluminum. The arrangements should be such that intercepting dust collectors, suitably grounded (see Chapter 5, Article 51), or the design of the ducts, will prevent aluminum dust from passing into the fan; in all cases, however, it is advisable that the fan blades or propellors and the fan housing be made of nonsparking material in case of a temporary bag leak, etc. In no case shall the design be such that the dust is drawn through the fan before entering the final collector. Personnel shall not be permitted within 50 feet of the fan during operation. This means that the fan and associated equipment shall be shut down for oiling, inspection or preventive maintenance. If the area must be approached during operation for pressure test or other technical reasons, it must only be done under the direct supervision of competent technical personnel and with the knowledge and approval of the operating management. Any fans into which dust may accidentally enter shall be placed outside of the dust-making building and outside of buildings where powder is drummed, screened, stored or otherwise handled in quantity. Fan bearings should be equipped with suitable instruments for recording the temperature therein and with an indicating device to give warning when a dangerous degree of heating is reached. When the fan is belt driven, a vibration-sensitive device may be attached to the outside end of the fan drive shaft, with an indicating device to give warning when a dangerous degree of vibration is reached.

CHAPTER 4. ELECTRICITY FOR LIGHT AND POWER.

41. Electrical Wiring and Equipment.

411. All electrical wiring and equipment shall conform to the National Electrical Code, NFPA No. 70, or to the Canadian Electrical Code, whichever is applicable. All parts of manufacturing buildings shall be considered Class II, Division 1 locations under Articles 500 and 502 of the National Electrical Code (Section 18

of the Canadian Electrical Code) except offices and similar locations so occupied and segregated as to be reasonably free from dust, and so classed by the authority having jurisdiction.

42. Requirements of National Electrical Code.

421. Attention should be specifically directed to the requirements of the National Electrical Code, NFPA No. 70, or of the Canadian Electrical Code for the location of transformers, type and location of motors, generators and their control equipment, cables, fuses, circuit breakers, conduits and lights of all types.

43. Special Provisions.

431. Provision should be made for remote control of the electrical circuits so that light and power in any dust-making building may be cut off by switches outside of the building at a distance of at least 4 feet from the nearest doorway. It should also be arranged that the power of the whole plant can be cut off by switches located at one or more central points, such as the office, watchman's booth, etc. All electrical equipment shall be inspected and cleaned periodically. Where flashlights or storage battery lamps are used, they should be of a type approved for the purpose.

CHAPTER 5. CONTROL OF STATIC ELECTRICITY.

51. Grounding Machinery to Remove Static Electricity.

511. Grounding machinery to remove static electricity produced in dust making and collecting is vital for safety. It should be thoroughly done according to Recommended Practice on Static Electricity, NFPA No. 77, and the certain additional precautions described in sections 734 and 912 of this standard, not only for stamp mortars or other mills, fans and conveyors in all parts of the plant where dust is made or handled, but also for all dust screens, cyclone collectors, bag collectors, and screen-cloth collectors. These several kinds of cloth collectors and screens, if not themselves metallic, should have fine noninsulated, nonferrous wire enmeshed or woven with the cloth or otherwise securely fastened into it at suitable intervals, and should be grounded.

CHAPTER 6. PREVENTION OF ACCUMULATION OF ALUMINUM POWDER OR DUST.

61. Cleaning Methods and Systems.

611. Dust shall not be permitted to accumulate. Good housekeeping is a factor of utmost importance. To this end an adequate vacuum sweeping system is recommended, although soft push brooms may be used. If portable vacuum cleaners are used, they should employ a highly efficient wet collecting system ahead of the vacuum exhauster. If dry collectors are used, they shall be located outdoors and away from all working areas and personnel. In all cases, the entire vacuum system shall be thoroughly grounded electrically, the hose shall be conductive and the pickup nozzle shall be of metallic, minimum sparking material. Each time the stamps or other dust-making machines are charged and/or discharged, all dust and other material spilled on open surfaces of the machinery or the floor of the building shall be promptly and thoroughly removed. When vacuum cleaners are employed, bulk accumulation of powder and material shall be removed by soft push brooms and nonsparking scoops before the vacuum sweeping equipment is used. Care shall be taken to avoid sucking water into the vacuum pickup nozzle to avoid caking of damp aluminum in the hose, etc. The electrical system shall be suitable for use in Class II, Group E atmospheres, that is, the electrical system shall be aluminum dust-ignition proof.

62. Cleaning Frequency.

621. Competent supervision and periodic cleaning should always be maintained, and the foremen should be alert to prevent the accumulation of excessive dust on any portions of buildings or machinery which are not regularly cleaned in daily operations. Regular periodic cleaning, with all machinery idle and power off, should be carried out as often as local conditions require it to maintain safety, but in any case at least once a week.

63. Location of Discharge Receptacles of Dust Collectors.

631. The dust collected by vacuum cleaner nozzles or brushes or otherwise and drawn through an evacuating pipe equipped with antiflash-back valves and explosion vents located outside the building shall be discharged into a suitable receptacle located outside the dust-making building. Each piece or group of such equipment shall be surrounded with a tight, strong, steel shield, preferably

cylindrical, open at the top and closed at the bottom and designed to withstand an instantaneous shock pressure of 200 pounds per square inch, so that, if an explosion should occur in dust-collecting receptacles, its full force and flame would be diverted upward.

64. Fans and Other Air Moving Equipment.

641. Fans and other equipment for moving the air shall be so placed that the entrance of dust is minimized, or else enclosed as above specified. They should have ball or roller bearings, and, when used for pneumatic conveying of dust from a machine or group of machines, they should be electrically interlocked with the power supply for such machines so that, in case the fan stops, the machine will stop making dust.

CHAPTER 7. PREVENTION OF IGNITION OF ALUMINUM POWDER.

71. General Precautions.

711. In the operation of the plant every precaution shall be taken to avoid the production of sparks from electrical faults or from either static electricity or sparks caused by impact, such as that of steel or iron articles or stones upon each other or upon concrete. The leakage of water in or into any building where it can come into contact with any aluminum powder shall be prevented to avoid spontaneous heating and ignition therefrom. The electrical heating to a high temperature of any wire or resistance element in a dusty or dust-producing building and the development of serious local heating in machinery, due to friction, should likewise be prevented. The installation of thermostats connected by relays with bell or other indicators may be advisable in some parts of the plant. All electrical components of thermostats, relays, etc., shall either be suitable for use in Class II, Group E atmospheres, that is, the components shall be aluminum dust-ignition proof, or shall be located outside of the buildings in dust-free areas.

72. Removal of Tramp Metal and Stray Pebbles.

721. Approved magnetic separators of the permanent magnet or self-cleaning electromagnetic types or approved pneumatic separators or screens should be installed in an approved manner ahead of all mills, stamps or pulverizers to remove tramp metal from the pieces of aluminum going to the mills or stamps, and these pieces

should also be carefully examined to remove pebbles or other foreign material which might, in subsequent operations, produce frictional sparks of sufficient intensity to ignite the aluminum powder. Any electro-magnets shall be suitable for use in Class II, Group E atmospheres, that is, the magnets shall be aluminum dust-ignition proof.

73. Bearings.

731. Ball or roller bearings properly sealed against dust shall be used generally for line shafts or other high-speed equipment, instead of plain bearings, because of the difficulty of maintaining proper lubrication of the latter for preventing their heating. Any open bearings which have to be used should be protected as thoroughly as possible against the ingress of aluminum dust and, on high speed equipment, should be equipped with automatic hot journal alarms. Bearings should be of the outboard type, protected by dust seals or packing glands lubricated or packed with permanently lubricated packing. A 5 per cent oxygen-bearing nitrogen or a compatible liquid may be continuously forced through the packing gland if necessary. In any case, before opening up seals or packing glands they shall be thoroughly "wetted down" with a high flash solvent or oil to prevent rapid oxidation of any accumulated aluminum with fresh unoxidized surfaces, which without such protection will ignite violently.

732. Internal machine clearances shall be maintained to insure against jamming against the walls of any material which may enter the equipment.

733. Slurry or solvent pumps should be installed with proper controls to make sure they will be shut down if they run dry. They should also be protected against the possibility of sucking in air from empty tanks or from leaky suction lines.

734. Electrostatic grounding shall include grounding across the lubricating film (by use of current collector brushes or "jumpers") for all bearings. All alarms and actuating equipment shall be suitable for use in Class II, Group E atmospheres, that is, alarms and actuating equipment shall be aluminum dust-ignition proof, or be located outside the building in a dust-free area.

74. High Temperature Warning.

741. Cyclone and bag collectors should be equipped with suitable instruments for recording the temperature therein and with an indicating device to give warning when a dangerous degree of heating is reached. The temperature limit may be set by the ignition temperature of the collector material (i.e., well below cloth

ignition temperature of cloth bags) or may be limited to stay well below the ignition temperature of the aluminum dust-air mixture as in the case of cyclone type collectors. Synthetic fibers which tend to accumulate high static charges shall not be used to construct bags. Polishing equipment should also be equipped with temperature recording instruments, to indicate to the operators any tendency toward excessive heating. All such temperature recording instruments should preferably give their indications and make their record at easily observed central locations so the men in responsible charge may receive warning and take action to remedy the hazardous conditions. All alarms and actuating equipment shall be suitable for use in Class II, Group E atmospheres, that is, alarms and actuating equipment shall be aluminum dust-ignition proof, or be located outside the building in a dust-free area.

75. Open Flames, Cutting and Welding Equipment, Powder-Operated Tools.

751. No open flames or electric or gas cutting or welding equipment shall be permitted within the buildings housing the powder-producing or handling machinery during operation. If it becomes absolutely necessary to use such equipment for making repairs, all machinery in the room or section of the building where the repairs are to be made shall be shut down and the entire room or section with its machinery shall be thoroughly cleaned to remove all accumulations of aluminum powder. Operators of cutting or welding torches should be required to obtain a permit from the safety or fire protection officer of the plant before using their equipment under any condition around aluminum powder plants. Attention is called to the hazardous conditions that may exist either inside or outside of the plant if cutting torches are used in dismantling dust collectors or powder-producing machinery before all dust accumulations have been removed.

752. POWDER-OPERATED TOOLS: Gun-type tools using powder or cartridges for driving pegs or pins into concrete, brick, steel, etc., shall not be used where flammable dust or dust clouds are present. When the use of this type of equipment becomes necessary, all dust-producing machinery in the area shall be shut down; all equipment, floors and walls shall be carefully cleaned; and all dust accumulations shall be removed. A careful check shall be made to be sure that no cartridges or charges are left on the premises where they could enter equipment or be accidentally discharged after operation of the dust-producing or handling machinery is resumed.

76. Spark-Producing Tools.

761. Aluminum, copper or bronze metal tools, including shovels, and not iron or other spark-producing tools, should be used in any dust-making building except when that part of the plant is stopped, and then only after thorough removal of dust accumulation. This rule shall also be followed in dismantling either inside or outside of the plant any discarded powder-producing equipment that may contain dust accumulations. Not even nonsparking tools or other hard objects should be allowed to strike any other hard surface in a dusty atmosphere as the energy so dissipated, if applied to only a few grains of powder, can raise the powder temperatures to the ignition point.

77. Heating and Drying.

771. Heating and drying should be done only by hot air, the air to be heated by steam or hot water coils in a small offset to the building. In buildings which may have aluminum dust in them, the heating and drying should be forced by blower fans into each respective building through a heating unit. In the case of dusty buildings, the fans should draw in their air supply from the outside in order that no explosive dust accumulates in the heating chamber. Air used in the process shall have a dew point sufficiently low to insure that no free moisture can form at any point in the process.

78. Sweepings.

781. Powder or dust sweepings and other materials swept from the floor, machines, or other locations must be carefully screened to remove foreign matter before being placed in any machine for additional fabrication.

79. Starting Machinery after Shutdown.

791. All machines should be thoroughly cleaned and be absolutely dry before they are charged with metal and placed in operation.

CHAPTER 8. ALUMINUM POWDER STORAGE.

81. Packing and Storage.

811. The aluminum powder product, the conveyance of which is referred to in Article 32, and the collection of which is to be in a separate building from the dust-making building, should be packed into steel drums as soon as possible, and these drums tightly sealed and stored in a dry location until they are ready to be shipped from the plant or repacked. Open bin storage is dangerous unless the bin is purged and maintained with a gas atmosphere of the character described in Article 322.

CHAPTER 9. WET MILLING OF ALUMINUM POWDER.

91. Prevention of Ignition.

911. SPONTANEOUS HEATING: When aluminum is milled or otherwise comminuted in the presence of a liquid which is inert chemically to the metal, the air-dust explosion hazard is eliminated. When the resulting product is subsequently exposed to air such as in filtering or drying, any unoxidized new surface produced during comminution will react and may generate sufficient heat to cause spontaneous ignition. To prevent this, it is imperative to have sufficient oxygen present in the milling or other comminuting operation, or in slurries ahead of filters and blenders, to at all times oxidize the new surface as it is formed. Addition of a milling agent, such as stearic acid, does not eliminate the necessity of maintaining an adequate supply of oxygen to prevent the subsequent spontaneous ignition hazard. During milling, where fresh surface is being developed rapidly, the oxygen content should be maintained at no less than 8 per cent. For aluminum being slurried in tanks or being processed in blenders or other equipment, where new surface is not being developed rapidly, the oxygen content can be reduced to a minimum of 4 per cent. If the oxygen is supplied as a constituent of air, the dew point of the air must be maintained substantially below that which could introduce a free moisture problem.

912. STATIC SPARKS: Mill bearings shall be grounded across the lubricating film by use of current collector brushes to provide for continuous grounding from the mill through to mill supports, piping, etc.

913. FLAMMABLE VAPORS: Adequate ventilation, forced or otherwise, shall be maintained in all rooms handling solvents to reduce vapor hazards from accidental spillage.

CHAPTER 10. FIRE FIGHTING METHODS.

101. Categories, Aluminum Fires.

1101. Aluminum fires should be considered in two separate categories:

1. Those where the aluminum is in a paste or slurry with an organic solvent.
2. Those where the aluminum is in dry powder form.

102. Fires in Aluminum Pastes or Slurries.

1021. A fire in an aluminum paste or slurry in an organic solvent is, for all practical purposes, a solvent fire until most of the solvent has burned off to expose dry aluminum. The first attack on this type of fire should be with carbon dioxide which, if available in sufficient quantity, will adequately control and put the fire out. Automatic carbon dioxide systems with outlets designed to adequately cover all vulnerable areas are recommended. An adequate supply of back-up carbon dioxide cylinders and portable carbon dioxide extinguishers is also recommended. If the fire such as could develop in a paste or filter cake gives evidence of having started through spontaneous ignition, the carbon dioxide may temporarily put the fire out, but subsequent contact with air would cause re-ignition. To prevent this, the aluminum paste or cake should be immediately completely covered with dry sand or an acceptable proprietary dry extinguishing material.* The covered material shall be left unmoved until the temperature of the whole mass has dropped to ambient. When the temperature throughout the entire mass is not above ambient and no "hot spots" can be found, the covered material should be removed very carefully and in small unit quantities (i.e., no more than three gallons of material in a five gallon pail). Throughout the removal operation great care is necessary to avoid creating any dust-air mixture; the aluminum cake must be kept covered at all times and again covered after it is transferred to the conveying pails. An ample supply of dry extinguishing material shall be kept immediately available to re-cover the aluminum cake if any heating reaction is started.

1022. Water should be used on a solvent-aluminum fire only as a last resort, when the methods above have failed and the fire shows evidence of going out of control. In such case, the water

*NOTE: Several such proprietary materials are on the market. Tests should be conducted to determine acceptability of any particular extinguishing material.