Recommendations for storage and handling of aluminum powders and paste

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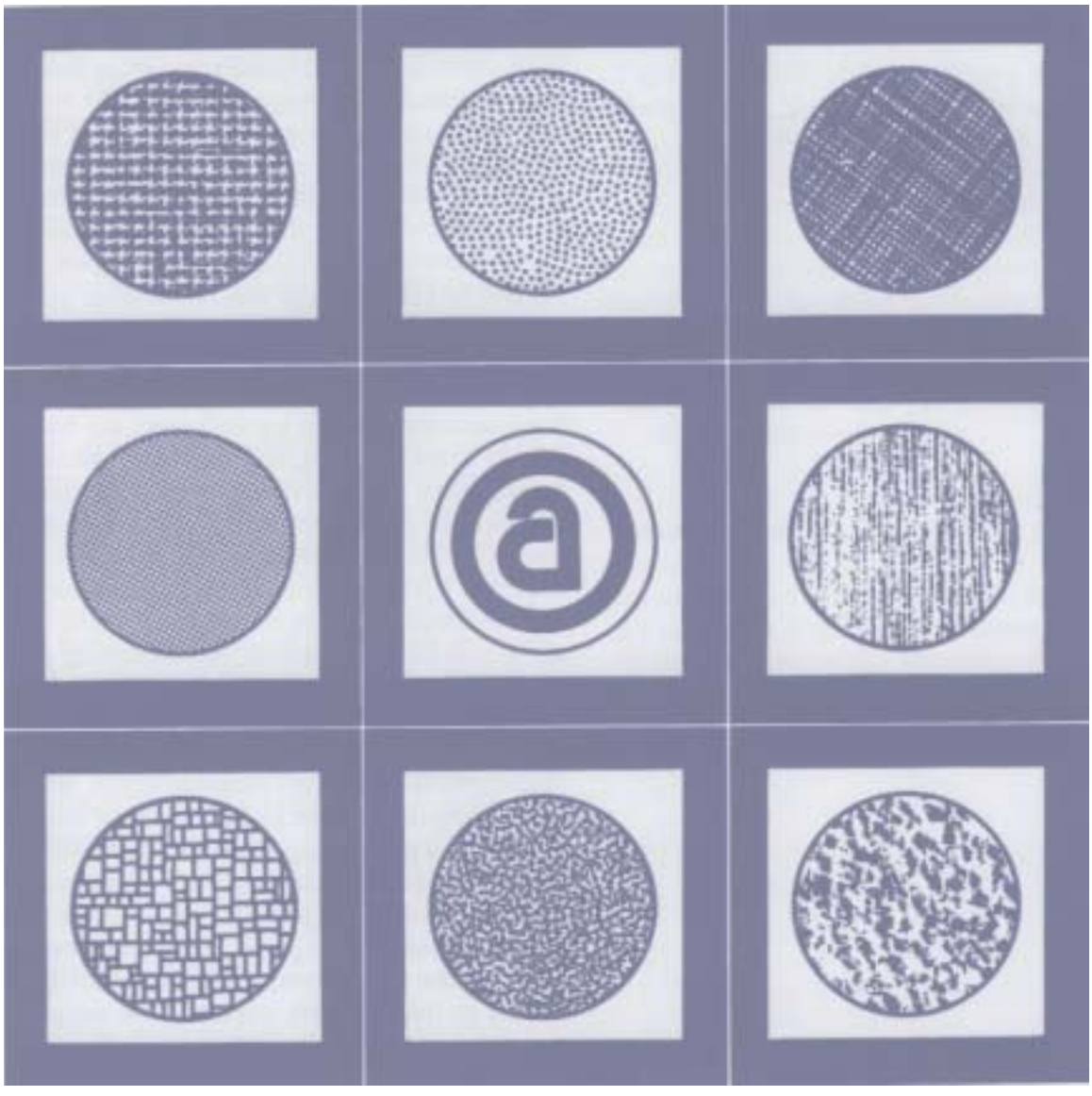
The Aluminum Association
Incorporated



About The Aluminum Association

The Aluminum Association Inc. (founded in November 1933) is the trade association for producers of primary aluminum, recyclers and semi-fabricated aluminum products, as well as suppliers to the industry.

Based in Arlington, VA, the Association provides leadership to the industry through its programs and services which aim to enhance aluminum's position in a world of proliferating materials, increase its use as the “material of choice,“ remove impediments to its fullest use, and assist in achieving the industry's environmental, societal, and economic objectives. Member companies operate about 200 plants in the U.S and many conduct business worldwide.

NOTICE

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GENERAL SAFETY RECOMMENDATIONS FOR STORAGE OF ALUMINUM POWDER AND PASTE

Aluminum powder and paste can be shipped, stored and used safely if proper attention is given to the maintenance of scrupulous housekeeping practices, and if the basic rules of safety contained in this brochure and other referenced sources are carefully followed. However, under certain conditions, aluminum powder and paste products can ignite and/or explode.

To provide a better understanding of the recommended safe procedures, the Safety and Property Protection Committee of The Aluminum Association's Pigments and Powder Division has prepared this brochure. These recommendations were compiled by the Committee from those sources listed in the Appendix, from the technical information presently available and from the Member's collective experience in handling aluminum powder and paste. Important source documents referenced in this brochure are National Fire Protection Association Standards Nos. 70, 77, and 484. Readers of this publication are encouraged to refer to these NFPA standards.

The Committee believes that if the recommendations contained herein are followed, the hazards related to the handling and use of aluminum powders and pastes will be substantially reduced. It should be recognized, however, that under some conditions, additional precautions may be required. Likewise, technical advances may uncover better ways of dealing with these materials. If you have any questions concerning aluminum powder and paste, please contact the manufacturer.

The suggestions and information in this brochure concerning the storage and handling of aluminum powder and paste are general in nature. Readers are advised to seek expert advice in connection with their individual handling and storage needs. The Aluminum Association and its member companies make no warranty and assume no responsibility or liability with respect to the suggestions and data contained herein.

DEFINITIONS

Aluminum Powder: Aluminum powder can be divided into three broad classifications: atomized, flake and granules. The length, width, and thickness of an atomized particle are all of approximately the same order, the length dimension probably not exceeding two or three times the thickness dimension. The length or width of a flake particle may be several hundred times its thickness.

Aluminum Paste: Aluminum paste is aluminum flake pigment homogeneously incorporated in a solvent. A variety of solvents may be employed, including both low and high flash point types. Detailed information on the fire and/or explosion hazards associated with a specific paste formulation may be obtained from the Material Safety Data Sheet supplied with the shipment and in discussions with the paste supplier.

Storage Areas: In this brochure, a storage area is understood to be an area where powder and paste are kept in closed containers. Requests for additional information on storage should be addressed to the supplier.

BACKGROUND

WHY POWDER BURNS

Chemically, aluminum has an enormous affinity for oxygen. This results in a thin film of aluminum oxide being produced almost instantaneously on the surface of the aluminum, when exposed to the atmosphere. The aluminum oxide film is inert and protects the underlying metal from further reaction.

When an aluminum powder particle is heated to a certain temperature known as the “ignition temperature”, the mass of the particle is so small, that the entire particle may oxidize almost instantly. Thus a pile of such particles will “burn.” Since flake particles have a much greater surface area per unit mass than atomized or granular particles, they will ignite more readily and burn faster than the other types of powder.

Generally, aluminum powders with a particle size of 40 mesh (420 microns) or smaller present a fire and explosion hazard.

WHY POWDER EXPLODES

Fine particles of aluminum powder, like some organic powders, such as flour, starch and coal dust, are easily dispersed in air where their low mass allows them to remain suspended or "float" in the air. These suspended particles will burn, similarly to particles in a pile, when the ignition temperature is reached. However, when dispersed in the proper proportion in the air, which allows the particles to mix with oxygen, the burning extends from one particle to another with such rapidity, that a violent explosion results.

Laboratory tests by the U.S. Bureau of Mines and others have established the proportions required for an explosion. These values extend through a wide range and very little aluminum powder is needed for an explosion to occur. Aluminum powder in the form of a dust cloud will ignite with as little as 6% oxygen present, the balance being nitrogen; less than 10% oxygen with the balance being helium; or 3% oxygen with the balance being carbon dioxide. Very small amounts of energy are required to ignite mixtures of aluminum powder and air.

COMMON SOURCES OF IGNITION

The discharge of static electricity will produce an electric spark that could raise the temperature of suspended powder particles in the vicinity of the spark above the ignition temperature — resulting in a fire or explosion. Electric switches, broken light bulbs, electric motor commutators, loose electric power connections — even a metal to metal impact — anything producing a spark can set off an explosion of aluminum powder suspended in air. Even continued metal to metal rubbing (as in a dry sleeve bearing) can generate enough heat to set off an explosion.

HEALTH ASPECTS

Information on health aspects of aluminum powder and paste is provided in Material Safety Data Sheets supplied by the aluminum powder or paste producer.

GENERAL SAFETY PRECAUTIONS

1. All electrical wiring, lights and equipment must be as specified by the latest version of the National Electrical Code, NFPA 70. Some locations may require electrical installations suitable for Class I or Class II locations per articles 500 through 504 of NFPA 70.
2. Great care must be taken to prevent the contact of water with aluminum powders. Leaks in steam lines, water lines, radiators or roofs should be promptly repaired.
3. Exercise good housekeeping practices in all areas where aluminum powder or paste is stored or handled. Guard against the accumulation of dust on floors, walls and other surfaces. Powder cleanup must be done only with squeegees or soft natural bristle brushes. Scoops used to pick up powder must be conductive and non-sparking. Synthetic bristle brushes and plastic or other non-conductive scoops must not be used, since they tend to accumulate strong static charges. Standard commercial industrial vacuum cleaners must not be used for cleaning. Only special machines specifically approved for use with combustible metal dusts may be used. Keep all rubbish, such as oily rags, papers and other combustibles out of the area.
4. Post "No Smoking" signs and enforce the rule. Do not use open lights, blow torches, welding torches or permit open flame of any kind in storage and handling areas.
5. Avoid friction sparks. Do not permit metal to metal or metal to concrete contact. In handling aluminum powders and pastes, use electrically conductive, grounded and non-sparking tools. Plastic and ferrous metals should not be used.
6. Keep aluminum powder and paste containers far enough away from steam pipes, radiators and other high temperature sources to prevent heating of the contents.
7. Keep all containers sealed except when opened for removal of material. Reseal containers immediately after each use to prevent contamination or, in the case of pastes, loss of solvent.

ALUMINUM POWDER AND PASTE STORAGE

1. Storage should be in rooms of noncombustible or limited combustible construction.
2. Aluminum powder and paste should be stored in the original shipping containers and kept tightly sealed.
3. Aluminum powder should not be stored in areas containing flammable liquids or other combustible materials, due to the differences in fire fighting methods.
4. Store sealed containers of aluminum paste in a dry room at a temperature below the flash point of the solvent.
5. Stack containers properly with ample aisle space. Keep stack height to a minimum.
6. Aluminum powder and paste must not be stored in the same area as incompatible materials such as oxidizers.
7. Safety aspects of bulk storage should be discussed with the powder or paste supplier.

SAFETY PRINCIPLES FOR HANDLING ALUMINUM POWDER AND PASTE

Rule I – Avoid any condition that will suspend or float powder particles in the air, creating a dust cloud.

1. In transferring aluminum powder, dust clouds should be kept at an absolute minimum. Handling should be slow and deliberate. Powder should be transferred from one container to another using a non-sparking, conductive metal scoop, with as little agitation as possible. Both containers should be bonded together and provided with a grounding strap.
2. In mixing aluminum powder with other dry ingredients, frictional heat should be avoided. The best type of mixer for a dry mixing operation is one that contains no moving parts, but rather affects a tumbling action, such as a conical blender. Introduction of an inert atmosphere in the blender is highly recommended since dust clouds are generated (See Rule II, item 4). All equipment must be well grounded.

Rule II – Eliminate all sources of ignition in powder and paste handling areas.

1. No smoking or smoking materials, including lighters or matches should be allowed in areas where aluminum powder, paste or dust are present.
2. No flame, spark producing or propellant actuated tools or activities should be carried out in an area where aluminum powder or paste are present. Where activities such as welding, cutting, grinding, or use of portable electric tools are necessary, a “Hot Work” permit system is strongly recommended.
3. Locate electric motors and as much electrical equipment as possible outside processing areas. Only lighting and control circuits should be in operating rooms. All electrical equipment must meet the National Electric Codes for hazardous installations. This includes flashlights, hazardous portable power tools and other devices.
4. The use of an inert gas to replace air can greatly increase the safety of many operations, particularly where it may be impossible to ensure that all sources of ignition are eliminated. It should be noted that completely inert gas not be used, since the aluminum powder would eventually, at some point in the process, be re-exposed to ambient atmosphere. At that time any unreacted surfaces, created by rupture of the oxide film during processing would re-oxidize, possibly creating sufficient heat to initiate either a fire or an explosion.
5. Impacts can produce sparks that will ignite aluminum powder. These can be caused by steel tools falling on a concrete floor or even an aluminum scoop falling on rusted iron. Non-sparking tools must be used where there is a possibility of impact sparks.

Rule III – Eliminate the generation of static electricity, where possible, and prevent static charge accumulations.

1. Bonding and grounding of machinery to remove static electricity produced in powder operations are vital for safety. Bonding and grounding should be done in accordance with the latest versions of Recommended Practice on Static Electricity, NFPA 77, and Standard for Combustible Metals, NFPA 484.
2. All moveable equipment, such as drums, containers and scoops must be bonded and grounded during powder transfer by the use of clips and flexible ground leads.
3. During transfer, powder must not be poured or slid on nonconductive surfaces. Such actions tend to build up static electricity.

4. Work clothing should be made of smooth, hard finished, closely woven fire resistant/fire retardant fabrics which tend not to accumulate static electric charges. Trousers should have no cuffs where dust might accumulate. Pockets, if present, should be designed in such a way as to eliminate the accumulation of dust. When static-dissipative footwear is used, a testing program should be implemented to ensure that no degradation of the static dissipative properties has occurred.

Rule IV – Take steps to limit the size of a fire or explosion and to hold any resulting damage to the very minimum.

1. Keep all containers sealed. Store these unopened in an area separate from handling areas.
2. When a drum of powder or paste is opened for loading or inspection, it should be closed and resealed as quickly as possible. This not only assures greater safety against fire from external sources, but also prevents possible entrance of tramp material or water from the air. In past instances, sealed drums of aluminum powder have withstood an external explosion and subsequent fire without ignition of the contents of the drum.
3. Consider the use of an inert gas which can be valuable in minimizing the hazard of handling powder in air.
4. All containers in work areas should be closed and sealed. Only those in actual use should be open at any time.

FIRE FIGHTING METHODS

Professional or volunteer fire fighters from outside the plant cannot be expected to be trained for the specific fire and life hazards associated with aluminum powder and paste fires. In the interest of their own safety, they should be directed by the plant's safety or fire fighting officer.

ALUMINUM POWDER

Since it is almost impossible to extinguish a large aluminum powder fire, the fire must be controlled in its incipient stage.

Aluminum powder fires on reasonably flat surfaces may be controlled by blanketing the fire with a Class D dry extinguishent or ringing the fire with a dam of dry sand. This should be done with great care to avoid disturbing the powder and creating a dust cloud. Even a minor dust cloud may explode violently. Long handled shovels or scoops of non-sparking material should be provided for the application of dry extinguishing agents.

A properly blanketed or ringed fire will develop a hard crust of metal oxide which will ultimately exclude enough oxygen to cause self-extinguishment. After dispensing the extinguishing material, leave the area, close all doors leading to the area and seal them with sand. All fans and machinery, including dust collection systems should be shut down. The area should not be reentered until combustion has stopped and the material has cooled.

Water must not be used to fight an aluminum powder fire since water reacts with hot aluminum powder to produce hydrogen. Also, the force of a water stream could suspend the aluminum powder to form a dust cloud.

Where Class A, B, or C fire hazards exist in powder areas, extinguishers suitable for use on such fires must be labeled “Not for Use on Aluminum Powder Fires.”

ALUMINUM PASTE

A fire in aluminum paste normally begins as a solvent fire. The solvent fire can be fought with Class B extinguishing agents, however, halogenated or vaporizing liquid agents must never be used. Judgement must be exercised 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. Then the fire should be considered a powder fire, the use of a Class B extinguisher should be discontinued and a Class D agent or dry sand should be used. If the aluminum metal has ignited, it may continue to burn under a crust, without flames, and should not be disturbed.

It is very dangerous to use a water hose stream to fight a paste fire. The force of the stream could spread the fire and even suspend dried out flake powder into the air, causing a dust cloud which may explode.

Suitable, commonly used Class B extinguishing agents are dry chemical, foam and carbon dioxide. Carbon dioxide may be used to extinguish fires involving solvent-wetted aluminum. However, re-ignition may occur due to high localized heat or spontaneous heating. To avoid re-ignition, the residual material must be immediately smothered.

EXPLOSIBILITY CHARACTERISTICS FOR VARIOUS TYPES OF GRANULAR ALUMINUM POWDER

Shape of powder	Particle Size (d50) (µm)	Surface Area (BET) (m2/gm)	Minimum Explosible Concentration (MEC) (gm/m3)	Pmax d (psig)	P/dtmax (psi/sec.)	Kst (bar·m/sec.)	Sample Concentration that corresponds to Pmax and dP/dtmax	Minimum Ignition Energy (MIE) (mJ)	Limiting Oxygen Concentration (LOC) O2 (%)	Most Easily Ignitable Concentration (gm/m3)
Non-spherical, nodular or irregular	53	0.18	170	123	3,130	59	1250			
Non-spherical, nodular or irregular	42	0.19	70	133	5,720	107	1,250 – Pmax 1,000 – dP/dtmax			
Non-spherical, nodular or irregular	32	0.34	60	142	7,950"	149	1250	10		
Non-spherical, nodular or irregular	32	0.58	65	133	8,880	167	750 – Pmax 1,500 – dP/dtmax	11	Ignition@8.0% Non-ignition @7.5%	1,000
Non-spherical, nodular or irregular	30	0.10	60					10		
Non-spherical, nodular or irregular	28	0.11	55	140	6,360	119	1,000 – Pmax 1,250 – dP/dtmax	11		
Non-spherical, nodular or irregular	28	0.21	55	146	8,374	157	1500	11		
Non-spherical, nodular or irregular	9	0.09	65	165	15,370	288	750 – Pmax 1,000 – dP/dtmax	4		
Non-spherical, nodular or irregular	7	0.74	90	153	17,702	332	1,000 – Pmax 500 – dP/dtmax	12		
Non-spherical, nodular or irregular	6	0.15	80	176	15,580	292	750	3.5		
Non-spherical, nodular or irregular	6	0.70	75	174	15,690	294	500 – Pmax 1,000 – dP/dtmax	3		
Non-spherical, nodular or irregular	5	1.00	70					4		
Non-spherical, nodular or irregular	4	0.78	75	167	15,480	291	1,000 – Pmax 750 – dP/dtmax	3.5		
Spherical	63	0.15	120	101	1,220	23	1,250 – Pmax 1,000 dP/dtmax	N.I.**	Ignition@8.0% Non-ignition @17.5%	1,750
Spherical	36	0.25	60	124	4,770	90	1250	13		
Spherical	30	0.10	60	140	5,940	111	1000	13		
Spherical	25	0.53	55	150	9,330	175	750 – Pmax 1,250 – dP/dtmax	9		
Spherical	21	0.35	50	148	11,024	207	1,000 – Pmax 1,250 – dP/dtmax	10	Ignition@8.0% Non-ignition @7.5%	1,000
Spherical	15	0.50	45	148	10,812	203	1000	7		
Spherical	15	0.30	55					8		
Spherical	6	0.53	75	174	16,324	306	750	6		
Spherical	5	1.30		167	14,310	269	750		Ignition@6.0% Non-ignition @5.5%	750
Spherical	5	1.00	70	155	14,730	276	1250	6	Ignition@6.0% Non-ignition @5.5%	1,250
Spherical	3	2.50	95	165	15,900	298	1250	4		
Spherical	2	3.00	130							

NI** Did Not Ignite

Footnotes

1) The powders tested are representative samples produced by various manufacturers utilizing a variety of methods of manufacture, submitted for testing to a single, nationally recognized testing laboratory, at the same time.
2) Data for each characteristic was obtained using the following ASTM methods: MEC: ASTM E1515; MIE: ASTM E2019; Maximum Pressure Rise (Pmax), Maximum Pressure Rise Rate (dP/dt), Deflagration Index (Kst): ASTM E1226; Limiting Oxygen Concentration (LOC): ASTM (Draft, 2003).
3) Particle size data represents the d50 measurement determined by the laser light scattering technique.

REFERENCES

1. M. Jacobson, Austin R. Cooper, John Nagy, Explosibility of Metal Powders, U.S. Bureau of Mines Report of Investigation No. 6516.
2. National Fire Protection Association, No. 70, National Fire Code
3. National Fire Protection Association, No. 77, Static Electricity
4. National Fire Protection Association, No. 491M, Manual of Hazardous Chemical Reactions.
5. National Fire Protection Association, No. 484, Standard for Combustible Metals.

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