UNITED STATES DEPARTMENT OF LABOR
OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION

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OCCUPATIONAL SAFETY AND HEALTH GUIDELINE FOR ALUMINUM

INTRODUCTION

This guideline summarizes pertinent information about aluminum for workers and employers as well as for physicians, industrial hygienists, and other occupational safety and health professionals who may need such information to conduct effective occupational safety and health programs. Recommendations may be superseded by new developments in these fields; readers are therefore advised to regard these recommendations as general guidelines and to determine whether new information is available.

SUBSTANCE IDENTIFICATION

* Formula Al

* Structure (For Structure, see paper copy)

* Synonyms Metana, aluminum metal, aluminum powder, alumina fibre, aluminum bronze, aluminum flake, aluminum 27, aluminum dehydrated, metana aluminum paste

* Identifiers

1. CAS No.: 7429-90-5

2. RTECS No.: BD0330000

3. DOT UN: 9269 77 (molten); 1309 32 (aluminum powder, coated); 1396 40 (aluminum powder, uncoated)

4. DOT label: Flammable solid (aluminum powder, coated); dangerous when wet (aluminum powder, uncoated); Class 9 (molten)

* Appearance and odor Aluminum is an odorless, silvery-white, soft, ductile, metallic solid that can also be in a powdered form.

CHEMICAL AND PHYSICAL PROPERTIES

* Physical data

1. Atomic weight: 26.98

2. Boiling point (at 760 mm Hg): 2327 degrees C (4221 degrees F)

3. Specific gravity: 2.70 at 4 degrees C (39 degrees F)

4. Vapor density: Data not available.

5. Melting point: 660 degrees C (1220 degrees F)

6. Vapor pressure at 1284 degrees C (2343 degrees F): 1 mm Hg

7. Solubility: Insoluble in hot or cold water, concentrated nitric acid, and hot acetic acid; soluble in hydrochloric acid, sulfuric acid and alkalies.

8. Evaporation rate: Data not available.

* Reactivity

1. Conditions contributing to instability: Contact between aluminum powder and ignition sources may create a severe explosion hazard. Because it is strongly electropositive, aluminum corrodes rapidly in contact with other metals.

2. Incompatibilities: Aluminum is an extremely reactive metal. Contact between aluminum and acids, caustics, combustible materials, chlorinated hydrocarbons, and strong oxidizers should be avoided.

3. Hazardous decomposition products: None reported.

4. Special precautions: Aluminum may corrode in contact with other metals.

* Flammability The National Fire Protection Association has assigned a flammability rating of 1 (slight fire hazard) to aluminum (dust or powder).

1. Flash point: Data not available.

2. Autoignition temperature: Data not available.

3. Flammable limits in air: Data not available.

4. Extinguishant: Do not use water, carbon tetrachloride, or halon to fight fires involving aluminum. Control small fires with sand, talc, or sodium chloride. Dry chemical or carbon dioxide extinguishers are also acceptable. Fires involving aluminum should be fought upwind from the maximum distance possible. Keep unnecessary people away; isolate the hazard area and deny entry. Containers of aluminum may explode in the heat of the fire and should be moved from the fire area if it is possible to do so safely. If this is not possible, cool fire exposed containers from the sides with water until well after the fire is out, but be careful not to get water inside containers. Stay away from the ends of containers. Firefighters should wear a full set of protective clothing and self-contained breathing apparatus when fighting fires involving aluminum.

EXPOSURE LIMITS

* OSHA PEL The current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for aluminum is 15 milligrams per cubic meter (mg/m (3)) of air for total dust, and 5 mg/m(3) for the respirable fraction, as an 8-hour time-weighted average (TWA) concentration [29 CFR 1910.1000, Table Z-1].

* NIOSH REL The National Institute for Occupational Safety and Health (NIOSH) has established a recommended exposure limit (REL) for aluminum of 10 mg/m(3) for total dust, and 5 mg/m(3) for the respirable fraction, as a TWA for up to a 10-hour workday and a 40-hour workweek [NIOSH 1992].

* ACGIH TLV The American Conference of Governmental Industrial Hygienists (ACGIH) has assigned aluminum a threshold limit value (TLV) of 10 mg/m(3) for metal dust, as

a TWA for a normal 8-hour workday and a 40-hour workweek [ACGIH 1994, p. 12].

* Rationale for Limits The NIOSH limit is based on the risk of lung changes that may lead to pulmonary fibrosis [NIOSH 1992]. The ACGIH limit is based on the no adverse effect level of 2 mg/m(3) and studies involving exposures to aluminum at much higher concentrations [ACGIH 1991, p. 46].

HEALTH HAZARD INFORMATION

* Routes of Exposure Exposure to aluminum can occur through inhalation, ingestion, and eye or skin contact.

1. Effects on Animals: Aluminum metal is an irritant dust of low toxicity in experimental animals. Fine metallic aluminum powders inhaled by rats, hamsters, and guinea pigs did not cause pulmonary fibrosis [NLM 1992]. Rats exposed by inhalation to aluminum dust developed pneumonitis [Proctor et al. 1988]. Inhalation or intratracheal injection of aluminum dust caused infections in the respiratory system of the rats and rabbits exposed [NLM 1992]. Interstitial fibrosis with hyalinosis, emphysema, and hemorrhage were noted and reportedly led to the development of bullous emphysema, bronchopneumonia, and hemorrhagic pneumonia [NLM 1992]. In addition to the alterations of the lungs, changes in the walls of blood vessels, kidneys, spleen, liver, and meninges were also reported [NLM 1992]. Aluminum filings and splinters embedded into the skin did not induce a hypersensitive state [NLM 1992].

2. Effects on Humans: Aluminum dust is an eye and respiratory tract irritant in humans. Soluble aluminum salts are irritants when inhaled as aerosols [Hathaway et al. 1991]. Although inhalation of aluminum powder of particle size 1.2 um, given over 10- or 20-minute periods several times weekly resulted in no adverse health effects among thousands of workers over several years, several other studies report X-ray evidence of pulmonary fibrosis [Hathaway et al. 1991]. Some patients on long-term hemodialysis develop speech disorders, dementia, or convulsions. This syndrome is associated with increased concentration of aluminum in serum, brain, muscle, and bone [Amdur et al. 1991; Hathaway et al. 1991]. There is some evidence that Alzheimer's disease may be linked to aluminum content in the body [Amdur et al. 1991]. Analysis of the aluminum content in the brains of persons dying from Alzheimer's have shown increased levels, although brain aluminum levels vary greatly. A second correlating factor is that neurofibrillary tangles (NFTs) have been identified in both aluminum encephalopathy and in Alzheimer's disease [Amdur et al. 1991]. However, it has been shown that the NFTs produced by the two conditions are structurally and chemically different and that NFTs are present in several other neurological disorders. It appears that the aluminum content of the brain is less an issue relating to exposure to aluminum than an issue of a blood-brain barrier defect or compromise of some kind [Amdur et al. 1991].

* Signs and symptoms of exposure

1. Acute exposure: Acute exposure to aluminum dust has resulted in eye irritation.

2. Chronic exposure: The signs and symptoms of chronic exposure to aluminum metal dust include shortness of breath, weakness, and cough.

EMERGENCY MEDICAL PROCEDURES

* Emergency medical procedures: [NIOSH to supply]

5. Rescue: Remove an incapacitated worker from further exposure and implement appropriate emergency procedures (e.g., those listed on the Material Safety Data Sheet required by OSHA's Hazard Communication Standard [29 CFR 1910.1200]). All workers should be familiar with emergency procedures, the location and proper use of emergency equipment, and methods of protecting themselves during rescue operations.

EXPOSURE SOURCES AND CONTROL METHODS

The following operations may involve aluminum and lead to worker exposures to this substance:

* The processing and transportation of aluminum

* Use in electrical transmission lines

* Use in the construction, manufacturing, explosives, petrochemical, and paper industries

* Use in desalinization, cryogenic technology, permanent magnets, and as a substitute for copper

* Use in testing for gold, arsenic, and mercury

* Use in sugar refining, alloying metals, as a chemical intermediate, and in containers for fissionable reactor fuels

Methods that are effective in controlling worker exposures to aluminum, depending on the feasibility of implementation, are as follows:

* Process enclosure
* Local exhaust ventilation
* General dilution ventilation
* Personal protective equipment

Workers responding to a release or potential release of a hazardous substance must be protected as required by paragraph (q) of OSHA's Hazardous Waste Operations and Emergency Response Standard [29 CFR 1910.120].

Good sources of information about control methods are as follows:

1. ACGIH [1992]. Industrial ventilation--a manual of recommended practice. 21st ed. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

2. Burton DJ [1986]. Industrial ventilation--a self study companion. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

3. Alden JL, Kane JM [1982]. Design of industrial ventilation systems. New York, NY: Industrial Press, Inc.

4. Wadden RA, Scheff PA [1987]. Engineering design for control of workplace hazards. New York, NY: McGraw-Hill.

5. Plog BA [1988]. Fundamentals of industrial hygiene. Chicago, IL: National Safety Council.

MEDICAL SURVEILLANCE

OSHA is currently developing requirements for medical surveillance. When these requirements are promulgated, readers should refer to them for additional information and to determine whether employers whose employees are exposed to aluminum are required to implement medical surveillance procedures.

* Medical Screening Workers who may be exposed to chemical hazards should be monitored in a systematic program of medical surveillance that is intended to prevent occupational injury and disease. The program should include education of employers and workers about work-related hazards, early detection of adverse health effects, and referral of workers for diagnosis and treatment. The occurrence of disease or other work-related adverse health effects should prompt immediate evaluation of primary preventive measures (e.g., industrial hygiene monitoring, engineering controls, and

personal protective equipment). A medical surveillance program is intended to supplement, not replace, such measures. To detect and control work-related health effects, medical evaluations should be performed (1) before job placement, (2) periodically during the term of employment, and (3) at the time of job transfer or termination.

* Preplacement medical evaluation Before a worker is placed in a job with a potential for exposure to aluminum, a licensed health care professional should evaluate and document the worker's baseline health status with thorough medical, environmental, and occupational histories, a physical examination, and physiologic and laboratory tests appropriate for the anticipated occupational risks. These should concentrate on the function and integrity of the skin, eyes, and respiratory system. Medical surveillance for respiratory disease should be conducted using the principles and methods recommended by the American Thoracic Society. A preplacement medical evaluation is recommended to assess medical conditions that may be aggravated or may result in increased risk when a worker is exposed to aluminum at or below the prescribed exposure limit. The health care professional should consider the probable frequency, intensity, and duration of exposure as well as the nature and degree of any applicable medical condition. Such conditions (which should not be regarded as absolute contraindications to job placement) include a history and other findings consistent with diseases of the skin, eyes, or respiratory system.

* Periodic medical evaluations Occupational health interviews and physical examinations should be performed at regular intervals during the employment period, as mandated by any applicable Federal, State, or local standard. Where no standard exists and the hazard is minimal, evaluations should be conducted every 3 to 5 years or as frequently as recommended by an experienced occupational health physician. Additional examinations may be necessary if a worker develops symptoms attributable to aluminum exposure. The interviews, examinations, and medical screening tests should focus on identifying the adverse effects of aluminum on the skin, eyes, or respiratory system. Current health status should be compared with the baseline health status of the individual worker or with expected values for a suitable reference population.

* Termination medical evaluations The medical, environmental, and occupational history interviews, the physical examination, and selected physiologic or laboratory tests that were conducted at the time of placement should be repeated at the time of job transfer or termination to determine the worker's medical status at the end of his or her employment. Any changes in the worker's health status should be compared with those expected for a suitable reference population.

* Biological monitoring Biological monitoring involves sampling and analyzing body tissues or fluids to provide an index of exposure to a toxic substance or metabolite. Exposure to aluminum can be evaluated by analyzing the urine samples of workers exposed. Between 50 and 200 milliliters (Ml) of urine should be used for each sample and preserved with 5 Ml of concentrated nitric acid. Samples are extracted using a polydithiocarbamate resin. Analysis is performed using inductively-coupled argon plasma, atomic emission spectroscopy (ICP-AES). This method (No. 8310) is described in the 4th ed. of the NIOSH Manual of Analytical Methods.

WORKPLACE MONITORING AND MEASUREMENT

Determination of a worker's exposure to airborne aluminum is made using a pre-weighed (tared) low ash polyvinyl chloride (LAPVC), 5 microns. For respirable fraction sampling the filter cassette is preceded by a 10 mm nylon cyclone. Samples are collected at a maximum flow rate of 1.7 liters/minute (respirable fraction), 2.0 liters/minute (total dust) until a maximum collection volume of 816 liters (respirable fraction), 960 liters (total dust) is reached. The minimum collection volume is 408 liters for the respirable fraction or 480 liters for the total dust. Analysis is conducted by gravimetric analysis (weighing the filter). If the gross weight of the sample justifies analysis for aluminum, the sample can be further analyzed by using atomic absorption spectroscopy with a lithium borate fusion technique (this part of the method is partially validated). This gravimetric method is described in the OSHA Computerized Information

System [OSHA 1994] and is fully validated. NIOSH has published two methods (Method Nos. 7300 - elements, and 7013 - aluminum and compounds) for the sampling and analysis of aluminum. Both methods rely on mixed cellulose ester (MCE) filters for the collection of the material. The method for elements (# 7300) requires sample analysis by inductively coupled plasma-atomic emission spectroscopy (ICP-AES). The method for aluminum and compounds (# 7013) requires sample analysis by flame atomic absorption spectroscopy (FAAS) [NIOSH 1994].

PERSONAL HYGIENE PROCEDURES

If aluminum dust contacts the skin, workers should flush the affected areas with plenty of water, followed by washing with soap and water.

Clothing contaminated with aluminum dust should be removed, and provisions should be made for the safe removal of the chemical from the clothing. Persons laundering the clothes should be informed of the hazardous properties of aluminum.

A worker who handles aluminum should thoroughly wash hands, forearms, and face with soap and water before eating, using tobacco products, using toilet facilities, applying cosmetics, or taking medication.

Workers should not eat, drink, use tobacco products, apply cosmetics, or take medication in areas where aluminum or a solution containing aluminum is handled, processed, or storage.

STORAGE

Aluminum should be stored in a cool, dry, well-ventilated area in tightly sealed containers that are labeled in accordance with OSHA's Hazard Communication Standard [29 CFR 1910.1200]. Containers of aluminum should be protected from physical damage and should be stored separately from acids, caustics, combustible materials, chlorinated hydrocarbons, and strong oxidizers.

SPILLS AND LEAKS

In the event of a spill or leak involving aluminum, persons not wearing protective equipment and clothing should be restricted from contaminated areas until cleanup has been completed. The following steps should be undertaken following a spill or leak:

1. Notify safety personnel.

2. Remove all sources of heat and ignition.

3. Clean spill using conductive, non-sparking tools and brushes with soft, natural bristles.

4. Do not use water to clean up the spill.

5. Place the collected material in sealed containers for reclamation or disposal.

SPECIAL REQUIREMENTS

U.S. Environmental Protection Agency (EPA) requirements for emergency planning, reportable quantities of hazardous releases, community right-to-know, and hazardous waste management may change over time. Users are therefore advised to determine periodically whether new information is available.

* Emergency planning requirements Aluminum is not subject to EPA emergency planning requirements under the Superfund Amendments and Reauthorization Act (SARA) (Title III) in 42 USC 11022.

* Reportable quantity requirements for hazardous releases A hazardous substance release is defined by EPA as any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment (including the abandonment or discarding of contaminated containers) of hazardous substances. In the event of a release that is above the reportable quantity for that chemical, employers are required to notify the proper Federal, State, and local authorities [40 CFR 355.40]. Employers are not required by the emergency release notification provisions in 40 CFR Part 355.40 to notify the National Response Center of an accidental release of aluminum; there is no reportable quantity for this substance.

* Community right-to-know requirements Employers who own or operate facilities in SIC codes 20 to 39 that employ 10 or more workers and that manufacture 25,000 pounds or more of aluminum per calendar year or otherwise use 10,000 pounds or more of aluminum per calendar year are required by EPA [40 CFR Part 372.30] to submit a Toxic Chemical Release Inventory form (Form R) to EPA reporting the amount of aluminum emitted or released from their facility annually.

* Hazardous waste management requirements EPA considers a waste to be hazardous if it exhibits any of the following characteristics: ignitability, corrosivity, reactivity, or toxicity as defined in 40 CFR 261.21-261.24. Under the Resource Conservation and Recovery Act (RCRA) [40 USC 6901 et seq.], EPA has specifically listed many chemical wastes as hazardous. Although aluminum is not specifically listed as a hazardous waste under RCRA, EPA requires employers to treat waste as hazardous if it exhibits any of the characteristics discussed above. Providing detailed information about the removal and disposal of specific chemicals is beyond the scope of this guideline. The U.S. Department of Transportation, EPA, and State and local regulations should be followed to ensure that removal, transport, and disposal of this substance are conducted in accordance with existing regulations. To be certain that chemical waste disposal meets EPA regulatory requirements, employers should address any questions to the RCRA hotline at (703) 412-9810 (in the Washington, D.C. area) or toll-free at (800) 424-9346 (outside Washington, D.C.). In addition, relevant State and local authorities should be contacted for information on any requirements they may have for the waste removal and disposal of this substance.

RESPIRATORY PROTECTION

* Conditions for respirator use Good industrial hygiene practice requires that engineering controls be used where feasible to reduce workplace concentrations of hazardous materials to the prescribed exposure limit. However, some situations may require the use of respirators to control exposure. Respirators must be worn if the ambient concentration of aluminum exceeds prescribed exposure limits. Respirators may be used (1) before engineering controls have been installed, (2) during work operations such as maintenance or repair activities that involve unknown exposures, (3) during operations that require entry into tanks or closed vessels, and (4) during emergencies. Workers should only use respirators that have been approved by NIOSH and the Mine Safety and Health Administration (MSHA).

* Respiratory protection program Employers should institute a complete respiratory protection program that, at a minimum, complies with the requirements of OSHA's Respiratory Protection Standard [29 CFR 1910.134]. Such a program must include respirator selection, an evaluation of the worker's ability to perform the work while wearing a respirator, the regular training of personnel, respirator fit testing, periodic workplace monitoring, and regular respirator maintenance, inspection, and cleaning. The implementation of an adequate respiratory protection program (including selection of the correct respirator) requires that a knowledgeable person be in charge of the program and that the program be evaluated regularly. For additional information on the selection and use of respirators and on the medical screening of respirator users, consult the latest edition of the NIOSH Respirator Decision Logic and the NIOSH Guide to Industrial Respiratory Protection.

PERSONAL PROTECTIVE EQUIPMENT

Workers should use appropriate personal protective clothing and equipment that must

be carefully selected, used, and maintained to be effective in preventing skin contact with aluminum. The selection of the appropriate personal protective equipment (PPE) (e.g., gloves, sleeves, encapsulating suits) should be based on the extent of the worker's potential exposure to aluminum. There are no published reports on the resistance of various materials to permeation by aluminum.

To evaluate the use of PPE materials with aluminum, users should consult the best available performance data and manufacturers' recommendations. Significant differences have been demonstrated in the chemical resistance of generically similar PPE materials (e.g., butyl) produced by different manufacturers. In addition, the chemical resistance of a mixture may be significantly different from that of any of its neat components.

Any chemical-resistant clothing that is used should be periodically evaluated to determine its effectiveness in preventing dermal contact. Safety showers and eye wash stations should be located close to operations that involve aluminum.

Splash-proof chemical safety goggles or face shields (20 to 30 cm long, minimum) should be worn during any operation in which a solvent, caustic, or other toxic substance may be splashed into the eyes.

In addition to the possible need for wearing protective outer apparel (e.g., aprons, encapsulating suits), workers should wear work uniforms, coveralls, or similar full-body coverings that are laundered each day. Employers should provide lockers or other closed areas to store work and street clothing separately. Employers should collect work clothing at the end of each work shift and provide for its laundering. Laundry personnel should be informed about the potential hazards of handling contaminated clothing and instructed about measures to minimize their health risk.

Protective clothing should be kept free of oil and grease and should be inspected and maintained regularly to preserve its effectiveness.

Protective clothing may interfere with the body's heat dissipation, especially during hot weather or during work in hot or poorly ventilated work environments.

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