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Reference Data Sheet for Aluminum

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POTENTIAL PROBLEM AREAS

- Industrial accidents involving production of aluminum powders and paste
- Labeling, warnings, and markings [1]
- Transportation of aluminum powders and pastes [2]
- Waste disposal of aluminum powders and pastes [3]
- Storage and handling of aluminum powders and pastes [4]
- Dusts generated in processing and finishing aluminum and its alloys [5]
- Employee hazard communication [6]
- Work practices
- Facility design [7,8]

INTRODUCTION

Aluminum is the most abundant metal in the earth's crust, and the third most abundant element; however, elemental aluminum does not occur in nature. Bauxite ore is the principal source of aluminum. Aluminum is a silvery-white, light metal with a specific gravity of 2.70 and a melting point of 660 °C (1220 °F). Pure aluminum is soft and lacks strength, but can easily be formed, machined, or cast; has a high thermal conductivity; and has excellent corrosion resistance due to a protective coating of aluminum oxide formed on the surface (this coating is at times deliberately thickened in the process of "anodizing"). It is nonmagnetic and non-sparking, stands second among metals in the scale of malleability, and sixth in ductility.[9] Industrial forms of aluminum include commercially pure metal and alloys with other metals such as chromium, copper, iron, magnesium, manganese, nickel, titanium and zinc. Aluminum alloys may contain as much as fifteen percent of the alloying metals. In powder form, aluminum and its alloys are combustible in air and present a potential explosion hazard. In sheet or block forms, aluminum will not normally propagate or sustain combustion.[10]

REACTIONS AND INCOMPATIBILITIES

Hydrogen Generating Reactions

Aluminum is a very reactive metal, and the greatest industrial hazards associated with aluminum are chemical reactions. Aluminum is an excellent reducing agent, and should react with water readily to liberate hydrogen. However, the protective aluminum oxide coating protects it from reaction with moisture or oxygen. If the protective coating is broken, for example, by scratching or by amalgamation (the process of coating with a film of mercury in which the metallic aluminum dissolves; the aluminum oxide coating does not adhere to the amalgamated surface), rapid reaction with moisture and/or oxygen can occur. The significance of this reaction is dependent upon the quantity of aluminum available to react. Aluminum is also oxidized by heat at a temperature dependent rate.

Aluminum metal is amphoteric (exhibits both acidic and basic characteristics). Therefore, aluminum will react with acids or bases; both reactions liberate hydrogen, a flammable gas. However, aluminum does not react with concentrated nitric acid because the oxidizing potential of the acid contributes to the formation of the protective aluminum oxide coating.[11]

Thermite Reactions

Aluminum readily extracts oxygen from other metal oxides to form aluminum oxide with the simultaneous release of large amounts of heat (enough heat to melt the products of the reaction). For example, the reaction of aluminum with ferric oxide to produce liquid aluminum oxide and liquid iron produces temperatures approaching 3000°C (5400°F). This reaction, referred to as the "thermite reaction," has been used to weld large masses of iron and steel; when enclosed in a metal cylinder and ignited by a ribbon of magnesium has been used in incendiary bombs; and, with ammonium perchlorate added as an oxidizer, has provided the thrust for the space shuttle booster rockets.[12]

Dust Explosions

A dust explosion is a complex phenomenon involving simultaneous momentum, energy, and mass transport in a reactive multi-phase system.[13] Aluminum particles, when in dust, powder, or flake forms from operations such as manufacturing powder, grinding, finishing, and processing, may be suspended as a dust cloud in air and consequently may ignite and cause serious damage. If the dust cloud is unconfined, the effect is simply one of flash fire. If, however, the ignited dust cloud is at least partially confined, the heat of combustion may result in rapidly increasing pressure and produce explosion effects such as rupturing of the confining structure. Aluminum dust is not always easily ignitable, and, therefore, the hazard of dust explosions is often ignored.[14,15] Minimum explosive concentrations of aluminum dust have been reported upwards from about 40 grams per cubic meter (0.04 ounces per cubic foot) of air.[16]

IMPLICATIONS

Lack of awareness of the potential hazards and reactivities associated with aluminum powder may exist because:

- *Aluminum powder is naturally protected with a barrier of aluminum oxide which may prevent reactions at times;*
- *Thermite reactions usually require a strong ignition source and therefore do not often occur in unplanned situations, although optimum conditions could allow these reactions to occur;*
- *Aluminum dust is not always easily ignitable due to dependency upon particle size, air distribution, and other factors; and,*
- *A false sense of security may exist due to hazard reduction when dealing with coated aluminum powders and pastes. Although organic coatings or pastes may generally offer some protection against dust generation, should dust formation or a fire ensue, the organic compounds may act as additional fuel.*

To alleviate this lack of awareness, employee hazard communication, labels, warnings, and markings should adequately address the hazards associated with aluminum; storage and handling parameters should be based upon consideration of the physical and chemical properties of aluminum; and, adequate precautions for incidents which may involve transportation of aluminum powders and pastes should be assessed.

INDUSTRIAL PROCESSES/POLLUTION/WASTE

Aluminum is produced by the electrolysis of alumina which is usually obtained from bauxite ore. This production, referred to as the primary aluminum smelting industry, involves several operations, with each having associated solid wastes, sludges, effluents, and/or air emissions. In addition, molten aluminum may represent a special hazard due to thermal and quality control factors.[17,18]

Emissions of concern in the aluminum industry include hydrocarbons, total particulates, fluoride particulates, and gaseous fluorides. Typical emission control devices include spray towers, floating-bed scrubbers, venturi scrubbers, quench towers, electrostatic precipitators, multiple cyclones, and baghouses.[19] Wastewater pretreatment controls include conditioning, thickening, dewatering, conversion, and drying processes which should be designed with the consideration of the parameters of the sludge/effluent. [20] The United States Environmental Protection Agency has promulgated standards concerning air, water, and land pollution. In addition to the primary aluminum smelting industry, these standards may be applicable and/or relevant to other industries using aluminum, for example, aluminum die casting operations.[21]

The secondary aluminum smelting industry is essentially composed of industries involved in the remelting/recycling of aluminum (such as aluminum pigs, foundry returns and scrap). The process encompasses fluxing, alloying, degassing and demagging. Paint, dirt, oil, grease, degassing fluxes, and magnesium-reducing fluxes (such as chlorine) may additionally contribute to potential sources of environmental pollution and additional hazards. Controls selected are generally similar to those found in the primary aluminum smelting industry.[22]

IMPLICATIONS

Industries involved in producing or using aluminum may require specific facility design criteria, with consideration of the process, environmental pollution, and the hazards of using aluminum. For example, aluminum dust collection is desirable to reduce particulate emissions; however, the collected dust from a process may present the physical and chemical hazards of aluminum. Inerting potentially flammable atmospheres, such as those found in processes involving mixing of powders, may be appropriate. Processes involving wet verses dry methods (such as pollution control, milling, etc.) should also have design considerations concerning the properties of aluminum dust. Work practices for employees should encompass emergency procedures, general housekeeping, waste disposal procedures, and any special precautions required in the particular work setting.

HEALTH EFFECTS

Aluminum particles deposited in the eye may cause local tissue destruction. Aluminum salts may cause eczema, conjunctivitis, dermatoses, and irritation of the upper respiratory system via hydrolysis-liberated acid.[23] Aluminum is not generally regarded as an industrial poison, although inhalation of finely divided aluminum powder has been reported as a cause of pneumoconiosis.[24] In most investigative cases, however, it was found that exposure was not solely to aluminum, but to a mixture of aluminum, silica, iron dusts, and other materials.[25] Aluminum in aerosols has been referenced in studies involving Alzheimer's disease.[26] Most exposures to aluminum occur in smelting and refining processes. Because aluminum may be alloyed with various metals, each metal (e.g., copper, zinc, magnesium, manganese, nickel, chromium, lead, etc.) may possibly present its own health hazards.[27]

The American Council of Governmental Industrial Hygienists (ACGIH) recommends the need for five separate Threshold Limit Values (TLVs) for aluminum, depending on its form (aluminum metal dust, aluminum pyro powders, aluminum welding fumes, aluminum soluble salts, and aluminum alkyls).[28] The Occupational Safety and Health Administration (OSHA) has also established Permissible Exposure Limits (PELs) for aluminum.[29]

IMPLICATIONS

Aluminum dust is strongly fibrogenic. Metallic aluminum dust may cause nodular lung fibrosis, interstitial lung fibrosis, and emphysema as indicated in animal experimentation, and effects appear to be correlated to particle size of the dust[30]; however, when exposure to aluminum dusts have been studied in man, most exposures have been found to be to other chemicals as well as aluminum.

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