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From .....

To .....

Safety in Handling Aluminum Powders

G. M. BABCOCK and F. B. RETHWISCH *Reynolds Metals Co., Louisville, Ky.*

Chem. & Met. INTERPRETATION

Except for those people who work constantly with aluminum powders, sufficient respect for the explosibility of this material does not appear to exist. With the present widespread use of aluminum powders for the manufacture of military pyrotechnics, need has developed for the more widespread dissemination of information on safe practices in their handling and in manufacturing pyrotechnics. The article which follows is based on the experience gained by the Reynolds Metals Co. in many years of producing and handling metallic powders and is offered as a starting point in the development of safety programs for concerns engaged in or beginning operations in pyrotechnic work. Certain fundamental precautions are discussed by the authors as a service to the industry, but neither they nor their company assume liability of any kind in presenting this information.—Editors.

FLAKE ALUMINUM POWDER, somewhat similar to the material commonly used in aluminum paint under the rather misleading name of "aluminum bronze powder," is a valuable component of pyrotechnic mixtures used for flares and signals. The high surface area of a given weight of aluminum flake powder makes it easily ignitible when in the presence of oxygen or air. Burning, it evolves a tremendous amount of heat and light. Owing to its low apparent density, fine particles of the material tend to float in air with the attendant danger of violent explosion upon ignition, when a proper ratio of aluminum to oxygen is reached.

A somewhat different aluminum powder, the grained variety, consists of spheres, sausage shapes or irregular grains of aluminum, which are relatively hard to ignite. When mixed with oxygen-producing compounds, the grained powder will burn with the evolution of much heat and light. This material, however, has a high apparent density and low surface area which tends to keep it from suspension in air so that the danger of explosion or fire from aluminum "fog" is almost nil.

Both flake and grained aluminum are shipped in sealed drums with fully removable heads. These drums should be stored unopened in a separate area wherever possible, since if they are stored along with such chemicals as sulphur, nitrates and others of similar character, a fire from any cause would present a most serious problem. Whenever a drum of aluminum powder is opened for loading or inspection, it should be closed and re-sealed as soon as possible. This not only insures greater safety against fire from external causes but also limits the likelihood of tramp material getting into the powder, or of the powder absorbing water from the air. In one instance a sealed drum of flake aluminum withstood an aluminum dust explosion and subsequent fire without ignition of the drum contents.

There are few practical means of extinguishing fires involving aluminum powder or mixtures containing this powder. Anything which tends to disturb the burning mass may throw the aluminum into the air and result in a violent explosion of tremendous destructive power. It is true that dry sand, carefully placed over a pile of burning aluminum, will smother the flame, but in the excitement attending such a fire, there is danger that the sand will be thrown or shoveled on to the mass, and that the powder will be thrown into the air. There have been several cases where relatively harmless fires have been changed to serious and fatal explosions from this cause.

Consequently, the safer and more prudent rule is to instruct employees to walk out of the building in the case of an aluminum fire, shutting the door securely but as gently as possible to avoid disturbing the burning mass.

All employees should be instructed in procedures to avoid. They should understand thoroughly that water, carbon tetrachloride, fire foam, carbon dioxide and similar extinguishing agents should not be used on aluminum fires. Use of such materials will cause explosions. Night watchmen should be instructed to convey this information to any regular or volunteer group which attempts to extinguish an aluminum fire. Furthermore, the use of a fine spray of water from a stirrup pump, such as is used by civilian defense workers on incendiary bombs, should never be used on aluminum powder fires.

It is of utmost importance that local fire departments be informed of these precautions. The department should be provided with complete information and charts regarding those warehouses which contain aluminum, as well as those containing other chemicals. These charts should also be readily available to the watchmen and to the plant's own protection division at all times.

AVOIDING HAZARDS

A source of great danger in the handling of aluminum powder is the presence of foreign substances, particularly hard or metallic materials. Care should be taken to see that closing bolts, nails and similar bits of metal cannot contaminate aluminum powder or pyrotechnic mixtures.

Good plant housekeeping is one of the most effective methods in achieving plant safety and care must be taken particularly in the weighing, mixing and pressing rooms. As little material as is practical should be kept in one place at one time. Scoops for handling powders should be of non-sparking material and the handling should be slow and deli-

berate to reduce dusting to a minimum. Rooms in which powder is handled should be cleaned at frequent intervals, but never during weighing, mixing or pressing operations. All material should be kept in closed containers while cleaning is in progress. If oil is used in the pyrotechnic mixture, special care must be taken to insure that all oily rags or waste are deposited in closed safety cans away from the storage or loading areas. These rags must be disposed of daily. In cleaning, care must be taken particularly to keep all corners, window ledges beams, building steel and other resting places free from dust.

BUILDING PROTECTION

The buildings used for weighing, mixing and loading operations should, wherever possible, be so spaced and protected that fires or explosions in one unit cannot be communicated to other units. Construction should be adapted to the venting of explosions, using either a "soft" wall or roof, or a blow-out panel. All equipment should be located so that the operator has a free path to an outside door, without a mixing bench, press or mixer between him and the door.

All metal in the buildings should be grounded. This not only includes the equipment itself, but also metal window and door frames and other building elements. Clips connected to flexible grounded leads should be placed on all metal drums or other movable equipment. Only explosion-proof motors should be permitted, and for these the controls should be fully inclosed and non-arcing, located outside the workroom so that no worker need be in the mixing or pressing room from the time of starting these operations until they are completed.

All lights should be of a type approved for explosive operations and conditions. Particular care must be taken when automatic or manual tools are to be used in buildings for repairs or changes. When such work is to be carried out, the rooms must first be emptied of all ignitible material and thoroughly cleaned. Fatal explosions have been caused in dust-filled rooms by an arc from the switch of an ordinary flashlight. Therefore, only flash lights, electric lighting and power equipment carrying Underwriters' approval for use in explosive areas and where explosive vapors are encountered should be used.

Wherever possible, both the shoes of workers and the floors should be of a conductive but non-sparking type. Electrical discharges produced by static or lightning are the most difficult safety hazards to control. The danger from static charges produced by friction is greatest in cold, dry weather. Even walking on concrete or composition flooring in non-conducting shoes may produce sparks capable of igniting pyrotechnic mixtures or fine aluminum particles suspended in the air. Even the friction caused by aluminum powder poured from a scoop to a container can create high static charges on the aluminum particles. Particularly in the case of flake aluminum powder, considerable time is required to dissipate this charge.

Several types of non-sparking, conductive floors have been employed successfully.* Three types may be described briefly here, including (1) Magnesite flooring installed over a wood or concrete base, with conductive metal grids placed beneath the surface of the floor and properly grounded; (2) emulsified asphalt composition flooring with a conductive aggregate which also is laid over grounded metal grids, and (3) industrial graphite tile made of a conductive mastic, the edges of the tile being melted together with a hot iron on installation to provide a continuous surface. With this last mentioned type no metal grid is necessary, the tile itself being grounded at various points.

These views, from photos by the U. S. Army Signal Corps, show a thermite bomb demonstration at the Army War College, Washington, D. C.; the upper view shows the bomb beginning to explode, while the lower shows the climax of the explosion where the bomb, having reached a temperature of about 4,000 deg. F., is melting through the slab of steel on which it rests





* Further information on these floors can be secured from Armstrong Cork Co., Building Products Div., Lancaster, Pa.; the Flintkote Co., Industrial Flooring Div., 30 Rockefeller Plaza, New York, N. Y.) and the Hamphite Co., 111 Oley St., Brooklyn, N. Y.

The causes of static should be explained to employees, using simple illustrations such as the rubbing of silk in cold weather, or the combing of hair. Belt drives should not be used on machines in the mixing, pressing or loading rooms. Special care should be taken in screen rooms, since the friction of the particles passing over the screens and their temporary suspension and separation in air can build up high static charges. All metal in processing and storage rooms should be grounded and every possibility of a spark from machinery, from broken electric light bulbs, or from the dropping of steel tools should be guarded against. Properly grounded metal containers on spark-proof conductive flooring will permit more rapid dissipation of static charges than wooden containers. Mixers should be allowed to remain at rest for a short time before the mixture is removed, thus permitting any static charge induced in the metal particles in the mix to be conducted to ground. Simple electroscopes can be made to determine when a mixture is free of static charge.

Adequate lightning protection is an important requirement for the plant handling aluminum powders. The grounding of all metal window and door frames and approved lightning protection of all wiring will largely eliminate the possibility of high charges collecting before or during a thunderstorm and perhaps discharging to the ground with an accompanying flash or spark. Protection against actual lightning strokes is best left to authorities on this subject.[3] Many concerns shut down all mixing and loading operations during severe, nearby lightning storms, the employees leaving the processing rooms during that period. Radio sets are good indicators of approaching electrical storms, but if they are used, they should not be installed in the loading area owing to the hazard they introduce.

Highlights in Avoiding Aluminum Powder Explosions

1. All machinery and all metal door and window frames should be well grounded.

2. All mixing and conveying equipment should be constructed so as to minimize the escape of dust into rooms.

3. Spatulas, scoops, conveyors and the like should be of non-sparking materials.

4. Motors, as far as possible, should be kept in separate rooms, outside the workrooms. Where it is necessary to have them in the workrooms, they should be of the explosion-proof, dust-proof, splash-proof and water-proof type of squirrel-cage construction.

5. Dust should not be permitted to collect in workrooms; they should be cleaned several times a day, if necessary, although not while operations are going on.

6. Dust in the air should be kept at a minimum. Most people who do not work constantly with aluminum powder do not fully appreciate the explosibility of this material. Trostel and Frevert[1] state that the lower explosive limit for aluminum powder suspended in air varies with the method of ignition. With an electrically heated, glowing wire, or with an arc, the lower explosive limit was found to be at a concentration of 7.0 mg. Al per liter of air, and at a concentration of 13.7 mg. with an induction spark.

7. Lighting of rooms should be provided by dust-proof, explosion-proof bulbs.

8. If necessary to use flashlights, they should always be of an Underwriters'-approved type, for use in explosive atmospheres.

9. All bearings and gears should be kept well lubricated and protected from dust.

10. All employees should wear approved type clothing, without pockets or cuffs, if feasible.

11. Operators engaged in mixing should wear respirators as a health precaution.

12. Safety shoes of a type which are both conductive and non-sparking should be worn by operators.

13. Conductive flooring should be employed if possible.

14. Operators should be instructed that in case of fire, they should walk out and close the door of the room until someone in authority arrives to take charge.

15. Aluminum powders should be stored only in sealed drums and apart from other materials, especially oxidizing agents or easily oxidizable substances.

16. Only dry sand or Underwriters'-approved extinguishers should be used on aluminum powder fires.

17. Care should be taken to prevent foreign substances from getting into aluminum powder.

18. Building construction should follow the recommendations of the National Fire Protection Association.[2]

19. In general, it is advisable to follow most of the precautions usually observed in the handling of explosives.

MIXERS AND PRESSES

Machinery used in mixing and pressing operations should be equipped with outboard dust-proof bearings, which should be kept well lubricated. Excessive temperature rise in any part should call for an immediate shutdown. If a shaft or other part should freeze on a bearing surface, no attempt should be made to loosen the part by force, such as by a hammer blow on the shaft, as long as any ignitible material is in the room. Exposed ring gears or bevel gears should be protected from aluminum-powder-containing materials, liberal applications of a heavy grease minimizing this danger.

The clothing worn by plant employees should be kept clean and free from aluminum dust by frequent washing. Many concerns supply shirts and slacks to both male and female employees, the slacks being made without cuffs. There is a possibility of danger when employees wear their work clothes to their homes before changing. For example, a spark from a cigarette may easily cause fatal burns to a person whose clothing is filled with the dust of a pyrotechnic mixture. Owing to the possibility of static charges, silk and silk-like materials should not be worn at work by employees.

The ideal arrangement in locker rooms for employees is to use a double locker system with an intervening shower or washroom. With this method, a locker is provided for each employee at each side of the shower or washroom. The employee removes his work clothes and places them in the work clothes locker, then takes his shower and continues to his second locker on the other side of the shower room where he secures his street clothing. Thus his work clothes locker is always available for inspection by company officials or for the removal of soiled clothing for replacement with clean clothing. As previously mentioned, spark-proof and conductive shoes should always be worn by employees in the loading and mixing areas.

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