United States Patent Office

3,325,316

Patented June 13, 1967

1

3,325,316

PYROTECHNIC COMPOSITIONS OF METAL MATRIX WITH OXIDE DISPERSED THEREIN

Gilmour C. MacDonald, 55 Warwick Drive, Rte. 1, Shalimar, Fla. 32579

No Drawing. Filed Mar. 29, 1965, Ser. No. 443,673
6 Claims. (Cl. 149—17)

This invention relates to improvements in pyrotechnic compositions. More particularly, it concerns modification of light metals, particularly aluminum and magnesium, to form pyrotechnic materials particularly suitable for incendiary bombs, and related military devices.

Pyrotechnic compositions are used extensively both for industrial and military purposes. In the military field, incendiary bombs in some operations are used to a greater extent than high-explosive bombs. Also, use of incendiary materials for antipersonnel devices has increased, particularly for guerrilla warfare. In the industrial field, pyrotechnics are used in heating devices, welding operations and numerous other applications. In all of these, cost and thermal efficiency are important factors and there is a constant demand for ways to improve the heat output of pyrotechnics per unit cost or unit weight.

Magnesium presently costs 50% more than aluminum, and, when burned in air, delivers only 5.9 kcal./g. whereas aluminum produces 7.4 kcal./g. On a cost basis, it follows that magnesium is one-half as efficient as aluminum in producing heat. Aluminum also excells on the basis of volumetric efficiency, producing 20 kcal./cc. versus only 10 kcal./cc. for magnesium. In this same connection, many incendiaries with magnesium bodies require cast iron caps to insure the desired terminal velocity and penetration of the bomb.

The high heat conduction of aluminum is a major reason why metallic aluminum, except thin foil and fine wires, does not sustain burning in air and has not been fully exploited as an incendiary metal in competition with magnesium in spite of its great advantages. Other characteristics of aluminum also mitigate its use as an incendiary. Thus, it behaves differently than magnesium and will not easily ignite or burn in air because of a combination of reasons, i.e., high heat conductivity, the fact that Al_2O_3, the combustion product, is substantially bulkier than the original volume of aluminum metal, and the formation of an oxide film when the aluminum is first exposed to the air.

Pyrotechnic materials, if they are to deliver a maximum of heat to the target for incendiary useage, must make a maximum useage of atmospheric oxygen in the combustion process. The inclusion of an oxidizer or other reactant in the pyrotechnic formula tends to reduce the total yield of heat per unit weight. Frequently, however, it is necessary to add an oxidizer to make combustion in air possible, or to adjust the burning rate. For example, aluminum, when burned in air, yields 7,400 calories per gram, whereas thermite (finely divided aluminum with iron oxide as the oxidizer) delivers only about 800 calories per gram, and other thermite-type reactions can produce about 2,400 calories per gram.

Only oxygen and silicon are more abundant than aluminum in the earth's crust. From the viewpoint of availability, therefore, aluminum is to be preferred over magnesium in wartime as an incendiary material.

It is a principal object of this invention to provide means that will permit the efficient use of aluminum instead of magnesium, in incendiary bombs, and the like.

It is a further object of this invention to reduce or eliminate the need for a thermite-type igniting mixture in incendiary bombs of the type employing combustible metals.

2

An additional object of the invention is the provision of means for reducing the heat conduction of light metals in pyrotechnic compositions.

It is still a further object of this invention to provide new pyrotechnic compositions of light metals comprising means to adjust the burning rate of light metals in air and/or prevent flow of the pyrotechnic material from the point of bomb impact or combustion.

Another object of this invention is to permit use of light metals as an incendiary fuel without incurring the additional expense and hazard incident to powdering, flaking or granulating.

It is also an object to thicken light metals above the melting point so that additives of differing density can be mixed therein without undue separation.

Other objects and further scope of applicability of the present invention will become apparent from the detailed description given hereinafter; it should be understood, however, that the detailed description and specific examples, while inicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

These objects are accomplished according to the present invention by combining molten or semi-molten aluminum and/or magnesium with an oxidizer in proportions usually less than stoichiometric, to produce a homogeneous mixture of the two such that when the temperature of the mixture is raised above the melting point of said metal, the mass will have an apparent viscosity appreciably greater than the viscosity of the molten metal per se.

In most incendiary applications, efficiency will require that maximum useage be made of atmospheric oxygen, which dictates a less-than-stoichiometric percentage of oxidizer. Other factors which would make it impossible to specify precise formulations would include reactivity of the light metal chosen, reactivity of the oxidizer chosen, whether or not an additional thickening agent is used, whether or not the thickening agent enters into the reaction, burning rate desired, temperature desired, thickness of the metal section to be employed, desired ignitability, etc.

An approximately stoichiometric formulation for Thermite is:

	Percent
Powdered aluminum	25–28
Magnetic iron oxide, Fe_3O_4	72–75

A preferred embodiment of this invention, therefore, comprises melting 25% or more aluminum and homogeneously mixing 75% or less iron oxide therewith.

A preferred embodimennt of the invention comprises melting aluminum or magnesium in an oxygen-free atmosphere and homogeneously mixing iron oxide and silicon dioxide therewith.

The success of this invention is due in part to the discovery that it is possible to melt a light metal as hereinbefore defined and homogeneously mix it with a potentially highly reactive oxidizer for the metal without a highly exothermic reaction ensuing. The grinding or powdering of the light metal and oxidizer is thereby completely eliminated. This is apparently due to the fact that aluminum melts at 660° C. whereas the Thermite reaction of Fe_3O_4 and Al does not initiate below about 1500° C. Further, the success of the invention depends in part on the ability of the potentially reactive oxidizer to function as a thickening agent for the light metal and substantially increase the viscosity of the combined mass. In those incendiary bomb designs wherein the light metal body, magnesium, for example, becomes molten due to the action of a starting composition such as thermite, and finishes burning while in the molten state, a thickener will help retain the molten magnesium at the point of impact, insuring the greatest possible concentration of heat.

The operations of this invention differ from the thermite process of U.S. Patent 578,868 in that Goldschmidt employs "finely pulverized metallic aluminum" as the fuel for the reaction, whereas the present invention proposes metallic aluminum in the molten or semi-molten state at the time of adding the oxidizer. Each granule of Goldschmidt's "finely pulverized metallic aluminum" immediately forms an oxide film when the aluminum is first pulverized, and the film remains until the chemical reduction takes place in the thermite reaction. In contradistinction, there is relatively little aluminum oxide involved between the reactants prior to the ignition of the pyrotechnic material of this invention. The molten aluminum can be combined with the oxidizer/reactant while in an inert atmosphere if it is desired to ensure a minimum of aluminum oxide at the interface with the oxidant particles. This more intimate mixture of oxidizers with aluminum in the unoxidized state substantially reduces the temperature at which the reaction starts, and also facilitates ignition.

Various thickening agents may be employed in carrying out the invention, but iron oxides, as Fe_2O_3 or as Fe_3O_4, are the preferred oxidizers for use with light metals for incendiary purposes. The oxides of lead, manganese and silica, among others, can also be used.

Various proportions of the reactants or thickening agents may be employed in forming the new compositions and will depend to some extent on the agents used. Advantageously, between about 3–300 parts of reactant or thickening agent may be used for each 100 parts of the light metal. With the preferred additives, e.g., iron oxides, 5 to 150 parts of additive will be used for each 100 parts of aluminum or magnesium. Silica is a preferred additive to provide thickening action and advantageously 1 to 50 parts silica, or comparable thickening agent, is used for each 100 parts of light metal. The additive may be employed in various conditions, but is advantageously added as a finely subdivided material, i.e., having an average particle size of about 1 to 1000 microns.

Melting of the light metal and mixing the additives therewith can be accomplished in any suitable equipment. For addition of Fe_3O_4, magnetic mixing procedures may advantageously be used.

Those familiar with the theoretical heat output of aluminum or magnesium when burned with alkali nitrates or perchlorates frequently suggest that these should be better incendiary agents than thermite which produces much less heat. However, useage has shown that thermite is much superior because of the concentration of heat. Use of oxidizers such as the alkali nitrates and perchlorates results in dissipation of heat in the gases and evaporated reaction products such as the alkali oxides and chlorides. Even the metal oxides that are formed may reduce the heat concentration if they are carried away as a gas-colloidal fog. Further, the alkali oxides and chlorides that are formed tend to "fireproof" the adjoining area with molten salt particles.

In the complex reactions occurring in incendiary mixtures, other elements may act as incidental quasi-oxidizers. For example, when magnesium reacts with silicon dioxide, SiO_2, magnesium silicide, Mg_2Si, is formed. In this connection, it is noted that a commercial thickening agent marketed under the trade name of "Cab-O-Sil" is submicroscopic pyrogenic silicon dioxide. Because of the varying density of the additives to be mixed with the molten light metals during the manufacture of this pyrotechnic material, it may be desirable to use such a thickener to prevent separation of the components by reducing the fluidity of the liquid metals. For example, the specific gravity of Fe_3O_4 is almost twice that of metallic aluminum, and separation may occur unless the viscosity of the molten metals is kept high by thickening and/or mixing the components at or near the melting point.

Example 1

A pyrotechnic material and device were prepared by melting 240 parts of powdered aluminum metal in an alumina crucible heated in an electric resistance furnace and puddling at 840° C. into the molten metal 715 parts of ferric oxide which had been ground fine enough to pass a 200 mesh per inch standard screen and retained on a 325 mesh screen. The mixing of the molten aluminum and the ferric oxide was carried out vigorously for about 10 minutes in the air atmosphere of the furnace. During the heating and mixing, the temperature of the liquid mass was continuously recorded using a chromel-alumel thermocouple. No thermal breaks in the heating curve occurred. Visual observation of the mixing revealed no chemical reaction.

The molten mixture was cast in molds into the form of small hollow bombs of conventional elliptical shape and solidified. When thoroughly cooled, the bombs were removed from the mold and a first fire composition and fuse igniter were inserted into the hollow interior thereof. When dropped in broadcast fashion from aircraft from sufficient height to reach terminal velocity, the bombs ignited on impact and burned completely with intense heat.

In the foregoing example and remainder of the specification, all parts and percentages are by weight unless otherwise specified.

Example 2

The same charge was used as in Example 1, except that chunk aluminum was substituted for the powder, which was heated to 900° C. over a period of 30 minutes. Contents of the crucible after opening showed no reaction. The mixture, when solidified and fabricated into a ¼ inch diameter rod, could be burned in air when ignited with an oxy-acetylene torch.

Example 3

An identical charge to Example 2 was used. This run was heated to 1005° C. over a 50 minute period. Observations following the run were similar to Example 2.

From the foregoing, it will be apparent to those skilled in the art that there is herein disclosed a new and useful method for making pyrotechnic and incendiary materials. While specific examples have been given, applicant claims the benefit of a full range of equivalents within the scope of the appended claims.

I claim:

1. A solid pyrotechnic composition consisting essentially of 100 parts of a light metal selected from the group consisting of aluminum, magnesium and alloys thereof containing at least 25% by weight of said metal, 3 to 300 parts of finely divided iron oxide and 1 to 50 parts of finely divided silicon dioxide, the iron oxide and the silicon dioxide being homogeneously dispersed in a matrix of said light metal, said composition being capable of burning in air with production of intense heat, said composition having an apparent viscosity when melted in an inert atmosphere at a temperature between about 650 and 1300° C. substantially greater than molten group metal at the same temperature.

2. A solid pyrotechnic composition consisting essentially of 100 parts of aluminum and 3 to 300 parts of finely divided iron oxide, the iron oxide being homogeneously dispersed in a matrix of solid aluminum metal.

3. A solid pyrotechnic composition consisting essentially of 100 parts of aluminum and 1 to 50 parts of finely divided silicon dioxide, the silicon dioxide being homogeneously dispersed in a solid matrix of the aluminum metal.

4. A solid pyrotechnic composition consisting essentially of 100 parts of magnesium and 1 to 50 parts of finely divided silicon dioxide, the silicon dioxide being homogeneously dispersed in a solid matrix of the magnesium metal.

5. An incendiary device comprising as the major pyrotechnic material a mixture of iron oxide and aluminum metal, the iron oxide being in the form of a powder of average particle size between 1 and 1000 microns, the iron oxide powder being homogeneously dispersed in a solid matrix of the aluminum material.

6. A solid pyrotechnic composition consisting essentially of a light metal selected from the group consisting of aluminum, magnesium and alloys thereof containing at least 25% by weight of said metal and between 3 to 300 parts for each 100 parts of said metal of a finely divided oxide of iron, lead, manganese or silicon, said finely divided oxide being homogeneously dispersed in a matrix of said metal, said composition being capable of burning in air with production of intense heat, said composition

having an apparent viscosity when melted in an inert atmosphere substantially greater than molten group meta at the same temperature.

References Cited

UNITED STATES PATENTS

1,168,061	1/1916	Deppeler	149—3
3,026,200	3/1962	Gregory	75—206 X
3,078,553	2/1963	Tragert et al.	75—206 X
3,137,927	6/1964	Huegel et al.	75—206 X
3,139,682	7/1964	Grant	75—206 X
3,160,537	12/1964	Trafton	149—3
3,193,375	7/1965	Marx et al.	149—2 X
3,254,996	6/1966	MacDonald	149—37 X
3,286,334	11/1966	Hay	22—202 X

CARL D. QUARFORTH, *Primary Examiner.*

BENJAMIN R. PADGETT, *Examiner.*

S. J. LECHERT, Jr., *Assistant Examiner.*