United States Patent

Genden

[15] **3,645,810**

[45]

[54] SOLID FUEL COMPOSITION

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[73] Assignee: **The United States of America as represented by the Secretary of the Army**

[22] Filed: **June 14, 1955**

[21] Appl. No.: **515,564**

[52] **U.S. Cl.** **149/43,** 149/19, 149/20, 149/22, 149/44

[51] **Int. Cl.** **C06d 5/06**

[58] **Field of Search** 52/0.5, 15, 24; 149/43, 44, 149/19, 22, 20

[56] **References Cited**

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EXEMPLARY CLAIM

1. A solid fuel comprising a composition consisting of about 80 to 95 percent by weight of magnesium powder: 2 to 10 percent by weight of sodium nitrate; 2 to 10 percent by weight of a synthetic rubber cement; 6 to 8 percent by weight of stearic acid, and compressed into a solid having a specific gravity of from 1.30 to 1.70.

4 Claims, No Drawings

SOLID FUEL COMPOSITION

This invention relates to fuel compositions and more particularly to solid fuel compositions applicable generally to ramjet projectiles.

In the development of a solid fuel for a gun-launched ramjet projectile, many factors had to be considered, and one of the most important items of consideration was rigidity and strength of the solid fuel so that it could withstand the acceleration loads resulting from gun launching and still have burning characteristics such that it will ignite and burn satisfactorily at the conditions encountered during the flight of a gun-launched ramjet projectile.

A suitable solid fuel for the purpose above specified consists of atomized magnesium (325-mesh), sodium nitrate (40 to 100-mesh), rubber cement such as a medium brown syrup consisting of synthetic rubber, in acetone having a solids content of 37 percent, or its equivalent, and commercially available stearic acid or magnesium stearate. Other materials used include aluminum powder, amorphous boron, naphthalene flake, an alloy of 88 percent magnesium and 12 percent lithium, copper sulphate and polyvinyl chloride powder.

Many fuels were formulated and tested during the course of the solid-fuel investigation. A general classification of the types of fuels investigated may be made based on the major components present. Such a classification follows:

1. Simple magnesium fuels, which contain magnesium, oxidizer and binder.

2. Stearic acid fuels, which contain stearic acid or magnesium stearate in addition to the other components of the simple magnesium fuels.

3. Aluminum-magnesium fuels, which contain aluminum and magnesium powder as well as other materials.

4. Naphthalene-magnesium, naphthalene-aluminum, and napthalene-aluminum magnesium fuels, which contain some combination of naphthalene flake, magnesium powder and aluminum powder as well as other materials.

5. Boron-magnesium fuels, which contain amorphous boron and magnesium powder as well as other materials.

6. Miscellaneous fuels.

Early work on the development os solid fuels for a gun-launched ramjet projectile was centered about the general type of magnesium solid fuel developed previously. This fuel consists of magnesium powder, sodium nitrate and rubber cement. Sodium nitrate is an oxidizer used to maintain combustion, while the rubber cement is used as a binder to add strength to the fuel briquettes.

Several compositions of this type were tested over a range of pressures from 45 to 350 p.s.i.g. However, because of the high-burning rates obtained when this type of fuel is burned at high airflow and pressure and the erratic performance of the simple magnesium fuels as compared to fuels developed later in the program, little emphasis was placed on this class of fuel beyond the early stages of the program, after the development of the stearic acid fuels. Table VIII summarizes all the simple magnesium fuels treated during the period covered by this report.

As a result of the comparatively high-burning rates noted when burning simple magnesium fuels, and since observation of the flame resulting from these tests showed many small explosions during a run, it was decided that a more uniform briquette might result in more uniform burning characteristics. In order to accomplish this, small amounts of stearic acid or magnesium stearate were added to simple magnesium fuels as an internal lubricant when the fuel was pressed. In appearance, these briquettes were less grainy than those pressed from a simple magnesium fuel, indicating that a more homogeneous briquette was being formed.

When stearic acid fuels were burner-tested, the charges burned much more uniformly and generally resulted in higher thrust than simple magnesium fuels. Two charges were prepared, one made from a fuel containing 2 percent stearic acid and the other made from a simple magnesium fuel. Both charges burned about the same length of time. The thrust superiority of the stearic acid fuel is greater and the uniformity

of thrust production is better as there is a lack of any sudden increase or decrease of thrust when compared to the simple magnesium fuels.

Another result of adding stearic acid to the fuel is a reduction in burning rate. This is a desirable characteristic. When a fuel containing 2 percent stearic acid was compared to a simple magnesium fuel containing the same amount of sodium nitrate and rubber cement, it was found that the stearic acid fuel had an average burning rate of 3.1 inches per minute while the simple fuel burned at a rate of 5.3 inches per minute. When a similar fuel containing 2 percent magnesium stearate in lieu of stearic acid was tested, the burning rate was found to be 4.1 inches per minute. These tests were all made at comparable conditions, that is about 90 p.s.i.g. and 30° F. air temperature. This would indicate that although magnesium stearate retards the burning rate of magnesium fuels, it is not as effective as stearic acid for this purpose. Table IX shows the composition of stearic acid fuels tested while Table X is a similar table covering the magnesium stearate fuels.

TABLE VIII

Simple Magnesium Fuels

Composition Number	Percent Magnesium	Percent Sodium Nitrate	Percent Rubber Cement
A80	93	5	2
A81	91	5	4
A84	80	10	10
A89	90	6	4
A90	86½	7½	6
A91	82	10	8
A93	87	5	8
A94	84½	7½	8
A95	83	9	8

TABLE IX.—MAGNESIUM STEARIC ACID FUELS

Composition number	Percent magnesium	Percent sodium nitrate	Percent rubber cement	Percent stearic acid
A104	84½	7½	6	2
A107	82½	7½	8	2
A109	86	6	6	2
A110	84	6	6	4
A117	91	5	2	2
A118	83½	7½	7	2
A121	82½	7½	6	4
A122	81½	7½	7	4
A123	80½	7½	8	4
A124	90	6	2	2
A125	88	6	2	4
A126	83½	7½	6	3
A127	82½	7½	7	3
A128	81½	7½	8	3
A129	85	6	6	3
A130	89	6	2	3
A153	84	8	6	2
A154	82	10	6	2
A158	88	4	6	2
A159	92	2	4	2
A160	94	2	2	2
A161	96		2	2
A162	86½	7½	4	2
A164	79½	7½	10	2
A165	86	2	10	3
A175	87	5	2	6

TABLE X

Magnesium—Magnesium Stearate Fuels			Percent Magnesium Stearate	
A103	84½	7½	6	2
A111	82½	7½	6	4
A112	82½	7½	8	2
A113	86	6	6	2
A116	83½	7½	6	3
A131	86½	7½	4	2
A132	84½	7½	4	4
A137	85½	7½	4	3
A157	88	4	6	2

Several fuels incorporating aluminum powder were formulated in order to determine the effect of this material on burning rate, combustion efficiency and air specific impulse. An experimental investigation of aluminum as a ramjet fuel appeared desirable because of its higher heating value and its high density, allowing more fuel storage in a given volume. Many of the fuels contained both aluminum and magnesium while some fuels were composed of aluminum, sodium nitrate, stearic acid and rubber cement, eliminating magnesium completely. Work published on ignition temperature of magnesium alloys showed that magnesium alloys containing either 20 percent aluminum or 60 percent aluminum have the lowest ignition temperatures. For this reason, the majority of the bimetallic compositions tested contained either of these amounts of aluminum.

In general aluminum and aluminum-magnesium fuels burn more rapidly tan comparable magnesium fuels. However, suitable compounding does reduce the burning rate. These fuels burn well and completely when sufficient fuel-bed length and air is supplied. At lower airflows and shorter fuel-bed lengths, some difficulty was encountered in obtaining suitable burning of these fuels. They tended to quench or to burn with a long spark trail and produced little thrust.

Naphthalene is another material which was subjected to investigation as a solid fuel because of its properties; namely, high heating value per pound and low cost. Early in the study it was found that naphthalene, when burned as the major constituent in a fuel, vaporizes very rapidly and most of the fuel is blown from the combustion chamber before it can be burned. However, when combined with magnesium, it can be burned satisfactorily.

Three types of fuel-containing naphthalene were studied. They include naphthalene-magnesium, naphthalene-aluminum, and naphthalene-aluminum-magnesium fuels. In general, these fuels did not burn well at low airflows and pressures. When the airflow and fuel-bed length is increased, these fuels burn completely.

A brief investigation of boron as a ramjet fuel was also undertaken as part of the program. Use of boron would be advantageous because of the high heating value (23,000 B.t.u. per pound as compared to 10,800 B.t.u. per pound for magnesium). Several boron fuels utilizing linseed oil or nitro-cellulose as binders were investigated. None of these fuels were very satisfactory. However, a few boron-magnesium fuels were prepared, which included rubber cement as a binder. These fuels burned well, gave reasonable values of S_a (S_a = Air Specific Impulse, pounds thrust/pounds air/sec.) and appear generally to warrant further investigation.

The magnesium-lithium alloy was investigated because of its low ignition temperature. It is possible to ignite rods of this material with a match. Two fuels incorporating this alloy were tested, both of which contained 6 percent rubber cement, while one contained 5 percent sodium nitrate and the other 7½ percent sodium nitrate. The balance of the fuel in each case was the "88–12" magnesium-lithium alloy. Burner tests on these fuels show little difference from standard magnesium formulations, but use of this alloy may be helpful when conditions are such that a fuel containing pure magnesium will not burn.

Polyvinylchloride was investigated briefly for use as combustion promoter. Standard fuels containing 1 to 2 percent polyvinylchloride powder were prepared and tested. Somewhat smoother combustion appeared to result, but no greater difference in performance was noted.

Another factor which was studied is density of the fuel charge. In some of the early work on this subject, there appeared to be a tendency for combustion efficiency to increase with an increase in charge density. This was noted with charge specific gravities of less than 1.3. This may well have been due to the higher strength of the higher density charges which caused the fuel to be less susceptable to erosion. Very little difference in combustion efficiency was noted, however, when testing charges with specific gravity of 1.3 to 1.5.

From the tests made solid fuel briquettes of higher density were able to withstand greater acceleration loads than those of lower density. High-density magnesium solid fuels can withstand an acceleration of 31,000 times the force caused by gravity.

After many experiments it has been determined that the most desirable composition of matter suitable for the purpose consists of 80 percent to 95 percent by weight and atomized magnesium powder (325 mesh), preferably about 84½ percent; 2 to 10 percent by weight of sodium nitrate and preferably about 7½ percent; about 2 to 10 percent by weight of EC847 rubber cement and preferably about 6 percent, and about 2 percent by weight of stearic acid.

Another composition found to be quite satisfactory was one consisting of 81½ percent of magnesium; 7½ percent of sodium nitrate; 8 percent of EC847 rubber cement; and 3 percent of stearic acid. Still another composition consisted of 82 percent of magnesium; 10 percent sodium nitrate; 6 percent of EC847 rubber cement; and 2 percent stearic acid.

These materials are compressed into briquettes having 1.3 to 1.7 specific gravity; the higher the specific gravity, the greater the physical strength of the briquettes. The preferred specific gravity of the fuel may be anywhere in the above range (1.3 to 1.7) depending on the particular application for which the fuel will be used. Little change in burning rate is caused by an increase in specific gravity above 1.3.

Having now fully disclosed the invention, what I claim and desire to secure by Letters Patent is:

1. A solid fuel comprising a composition consisting of about 80 to 95 percent by weight of magnesium powder: 2 to 10 percent by weight of sodium nitrate; 2 to 10 percent by weight of a synthetic rubber cement; 6 to 8 percent by weight of stearic acid, and compressed into a solid having a specific gravity of from 1.30 to 1.70.

2. A solid fuel comprising a composition consisting of about 80 to 85 percent by weight of magnesium powder; 5 to 10 percent by weight of sodium nitrate; 6 to 8 percent by weight of a synthetic rubber cement; and 2 to 3 percent by weight of stearic acid.

3. A solid fuel comprising a composition consisting of about 84½ by weight of magnesium powder; 7½ by weight of sodium nitrate; 6 percent by weight of rubber cement; and 2 percent by weight of a synthetic stearic acid.

4. A solid fuel comprising a composition consisting of about 84½ percent by weight of magnesium powder; 7½ percent by weight of sodium nitrate; 6 percent by weight of rubber cement; and 2 percent by weight of a synthetic stearic acid, and compressed into a solid briquette having a specific gravity of from 1.30 to 1.70.

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PO-1050
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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,645,810 Dated 29 February 1972

Inventor(s) Seymour A. Genden

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

The issue date should be indicated as item 45 of patent. The issue date is 29 February 1972.

Signed and sealed this 20th day of June 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

PO-1050
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