

1

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MONOFUEL FOR UNDERWATER
STEAM PROPULSION

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5 Claims. (Cl. 52—5)

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a new high energy monofuel, more particularly, it relates to a high energy monofuel for producing heat for underwater steam propulsion.

It is an object of this invention to provide a high energy-density liquid fuel producing combustion products free from water-insoluble gases.

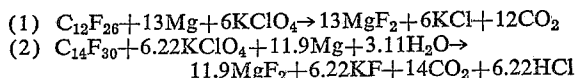
It is another object of this invention to provide a monopropellant fuel which is highly stable.

It is still another object of this invention to provide a monopropellant fuel which is non-toxic and non-corrosive.

It is a further object of this invention to provide a monopropellant fuel which is difficult to ignite or explode except with the special ignition devices incorporated in missile systems, and is hence very safe to handle.

It has been found that the above and other objects can be accomplished by a fuel comprising a non-explosive liquid fluoroalkane or liquid mixtures of fluoroalkanes, a light metal, such as, magnesium, aluminum, silicon and boron, and an oxidizing agent, such as, a metal perchlorate or manganese dioxide. The mixture of metal, fluoroalkane and oxidizer takes the form of a paste and is referred to as a fluidized fuel.

Fluoroalkanes were chosen as the fluidizing medium for the metal because of the non-detonability of the mixtures formed with them. Equations illustrating the reaction between the metals, fluoroalkanes and oxidizing agent are given below, the second reaction being based on a water reaction.



Thermochemical considerations indicate that the light metals mentioned above are highly feasible for the above type reactions; however, care must be exercised in the choice of fluorocarbons used, as previous attempts to use other fluorochemicals than the fluoroalkanes have resulted in highly explosive mixtures. In order to satisfy the requirement that the fuel be fluid, a liquid fluoroalkane or liquid mixtures of fluoroalkanes must be used. In compounding the fuel the perchlorate is preferably first mixed with the fluorocarbon and the metal added last.

It is preferable to use stoichiometric quantities of metal and fluorine for each other. This is not only in the interest of efficiency of the reaction but because any metal left over after the fluorine is used up may react with carbon to form carbides and this reaction consumes energy. Further, the metal carbides are abrasives and their presence in appreciable amounts would cause serious damage to turbine blades. While stoichiometric amounts of metal to fluorine are preferred, ratios of metal to fluorine varying from about 80 to 120 percent of stoichiometric are operative for providing an effective fuel. There should be sufficient oxygen available from the oxidizing agent to oxidize all of the carbon to carbon dioxide either directly or through the formation of carbonyl chloride

2

and the further reaction of this compound with water to form hydrochloric acid and carbon dioxide.

Compositions of fluoroalkanes and various metals were made up and tested for explosiveness, energy production and burning rate. Burning rate was measured by noting the time it took a column of the paste contained in a glass cylinder to burn from the top two inches down. Representative compositions selected from a large number tested are presented below, with results of tests, for the purpose of illustrating the invention only and are not to be considered as limiting the invention in any way.

In the examples, perfluorokerosenes with compositions corresponding to $\text{C}_{14}\text{F}_{30}$ and $\text{C}_{12}\text{F}_{26}$ were used. The particle size of the metal powder used was 1 to 30 microns.

Example I

A paste was prepared with the components proportioned for full oxidation of the carbon and full fluorination of the magnesium according to reaction No. 1 above. The composition of the paste mixture by weight proportions was as follows: $\text{C}_{12}\text{F}_{26}$ —35.7%, KClO_4 —46.6%, magnesium—17.7%. The paste had a specific gravity of 2.11 and a composition of 60.7% solids by volume. It did not detonate at full height of the drop hammer (2 kg. at 188 cm.). Samples confined in $\frac{3}{4}$ " iron pipe failed to detonate with a No. 8 blasting cap or a composition C-3 booster. Heat of reaction measured in a bomb calorimeter was 3,770 calories per cubic centimeter (1,790 calories per gram). The burning rate at 500 p.s.i. was 0.214 inch per second and at 1500 p.s.i. it was 0.99 inch per second.

Example II

A slightly more fluid paste was prepared based on a water reaction in accordance with Equation 2 above. Stoichiometric amounts of components were used. When burned without water this composition yielded 3,500 calories per cc. The burning rate at 100 p.s.i. was 0.54 inch per second. No detonation occurred with a blasting cap under the conditions described in the previous example. X-ray analysis showed that the double fluoride MgF_2KF was the principal ash component.

Example III

A paste was prepared of the following weight composition using both manganese dioxide and potassium perchlorate as oxidizing agents: $\text{C}_{14}\text{F}_{30}$ —29.3%, MnO_2 —52.5%, Al—14.3%, and KClO_4 —3.9%. The paste burned smoothly but slowly. Manganese dioxide is a very compact source of oxygen; (1.85 grams oxygen per cc., compared with 1.14 grams per cc. for liquid oxygen itself).

Example IV

A boron-magnesium paste of the following weight proportions was prepared: B—5.4%, Mg—4.6%, $\text{C}_{14}\text{F}_{30}$ —46.4% and KClO_4 —43.6%. This composition burned at the rate of .17 inch per second at 700 p.s.i. There is some slight advantage in the use of boron over magnesium as the combustion product boron trifluoride is a gas.

Example V

A silicon-magnesium paste was prepared according to the following weight proportions: $\text{C}_{14}\text{F}_{30}$ —46.3%, Si—10.6%, Mg—4.6% and KClO_4 —38.5%. This paste was found to have a burning rate of .092 inch per second at 700 p.s.i.

The monofuel of the invention is not limited to the specific fluoroalkanes used for illustrating it but other fluoroalkanes and mixtures thereof may obviously be used. It is required that the fluoroalkane or mixture of fluoroalkanes used be highly stable, liquid, form no non-condensable gases upon combustion, and have a freezing temperature below -10°C . and have a boiling tempera-

ture above 70° C. The freezing and boiling point limitations are required to meet operating conditions. Preferably, the monofuel should be non-toxic and non-corrosive in the interest of feasibility of handling it.

All of the compositions presented above were found to be non-explosive and to have very favorable heats of reaction. All of the paste compositions set forth above are non-inflammable at ordinary pressures, have low freezing points and high boiling points and are harmless to the skin. They all have good storage stability and possess other favorable surveillance characteristics.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A monofuel for underwater steam propulsion consisting essentially of a material selected from the group consisting of magnesium, boron, aluminum and silicon and mixtures thereof, a material selected from the group consisting of liquid perfluoroalkanes and liquid mixtures of perfluoroalkanes, having a freezing temperature below -10° C. and a boiling temperature above 70° C., and an oxidizing agent from the class consisting of manganese dioxide and alkali metal perchlorates, the proportion of metal to fluorine being approximately from about 80 to about 120 percent of the stoichiometric amount.

2. A fluidized monofuel for underwater steam propulsion consisting essentially of about 35 percent of a mix-

ture of perfluoroalkanes corresponding to the formula $C_{12}F_{28}$, about 17 percent magnesium and about 46.6 percent of potassium perchlorate.

3. A fluidized monofuel for underwater steam propulsion consisting essentially of about 29% of a mixture of perfluoroalkanes corresponding to the formula $C_{14}F_{30}$, about 14% of aluminum, about 52% of manganese dioxide, and about 4% of potassium perchlorate.

4. A fluidized monofuel for underwater steam propulsion consisting essentially of about 46% of a mixture of perfluoroalkanes corresponding to the formula $C_{14}F_{30}$, about 5.4% of boron, about 5% of magnesium, and about 44% of potassium perchlorate.

5. A fluidized monofuel for underwater steam propulsion consisting essentially of about 46% of a mixture of perfluoroalkanes corresponding to the formula $C_{14}F_{30}$, about 11% silicon, about 5% magnesium and about 39% potassium perchlorate.

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