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METHOD OF OPERATING A JET ENGINE AND FUEL COMPOSITION

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This invention relates to superior jet propulsion fuels and in particular to improved addition agents therefor.

Gas turbine jet propulsion devices particularly turbo-jet engines possess inherent limitations upon the amount of thrust obtainable from combustion in the principal combustion zone located upstream from the turbine. One limitation springs from materials of construction. Despite significant metallurgical advances in the development of heat resistant metal alloys there remains a maximum critical temperature beyond which turbine blades cannot be subjected without thermal deterioration. Thus, the amount of fuel supplied to the principal combustion zone must be carefully regulated so that on combustion this temperature is not exceeded.

To increase the amount of thrust hence power obtainable from turbo-jet engines, after-burners are employed. These are positioned downstream from the gas turbine and make use of residual available air for the combustion of additional fuel introduced rearwardly from the turbine. Thus, in the case of turbo-jet aircraft, after-burners are used intermittently in flight when bursts of speed are desired.

In practice, the fuel used in conjunction with after-burners is the same as used in the principal combustion zone. Because of the limited amount of oxygen available in the rearward portions of the jet combustion engine, it is desirable to use after-burner fuels having high heats of combustion per pound of air consumed. For this purpose, a suspension of finely divided magnesium metal in jet fuel has been proposed heretofore as after-burner fuel. However, the theoretical advantages to be obtained from such fuels have not been realized because of combustion difficulties. Because of the small volume of the engine in which combustion of after-burner fuel will be of advantage, the magnesium particles must ignite and burn during a very short period of time. However, it has been found that there is a considerable delay in initiating combustion of the individual metallic particles resulting in incomplete burning and thus reduction or nullification of the advantages of the high energy fuel. It is apparent, therefore, that there is a need for means of releasing fully the energy content of suspendable containing after-burner fuel. This invention in one of its forms relates to means of enhancing the burning characteristics of after-burner fuel.

Among the objects of this invention is that of providing superior jet propulsion fuel of enhanced burning quality. Another object of this invention is to provide new compositions of matter particularly adapted for use as addition agents for jet combustion fuel. A particular object is to provide improved after-burner fuel. Another object is to provide methods of operating jet combustion engines, including those equipped with after-burners. Additional objects of this invention will become apparent from the following description.

According to this invention the above and other objects are accomplished by a composition of matter comprising a suspendable consisting essentially of a finely

divided element having a heat of combustion of at least 8000 B.t.u. (British thermal units) per pound and at least 2000 B.t.u. per pound of air required for complete combustion and a melting point greater than about 400° F. to which element has been applied a coating of a light metal selected from the class of alkali and alkali-alkaline earth mixtures. In one of its preferred forms, this invention relates to additives for jet combustion fuel consisting essentially of a finely divided element having a heat of combustion of at least 10,000 B.t.u. per pound and 3500 B.t.u. per pound of air required for combustion and having a melting point no lower than about 950° F. substantially surrounded by a thin film of an alkali metal or a low melting alkali metal-containing alloy. Another preferred embodiment of this invention involves a composition of matter consisting essentially of finely divided boron, aluminum or magnesium coated with a thin film of an alkali metal.

Other preferred embodiments of this invention relate to superior jet combustion fuels comprising hydrocarbon fuels suitable for use in jet propulsion devices containing a suspension of the above-mentioned additives, and to methods of using my fuels.

ADDITION AGENTS

The core of the compositions of matter of this invention is a finely divided metal or metalloid element having a heat of combustion of at least 8000 B.t.u. per pound and at least 2000 B.t.u. per pound of air required for complete combustion. Elements having lower heats of combustion on either basis are unsuitable because the energy obtained from a practical amount of fuel or the energy that could be supplied to an increment of air would be too small. Elements meeting these heat of combustion requirements have energy contents sufficiently greater than ordinary hydrocarbons to be considered as desirable supplements to hydrocarbon fuels. Thus, use can be made of such metals as aluminum, beryllium, magnesium, silicon, titanium, and the metalloid, boron. Aluminum, boron, and magnesium are preferred because of their high combustion energy contents and availability.

The size of the particles to be coated ranges from about 10 to about 1000 microns. Such metal and metalloid powders may be prepared by methods involving abrasion, grinding, or milling or may be obtained by chemical means such as alkali metal reduction of metallic salts.

The surface of the particles before coating with light metals such as sodium, potassium or the like is preferably irregular. This enables both more intimate contact between the core and its coating and greater relative surface area per unit particle size upon which the coating metal can adhere or be adsorbed. An example of a metal powder having this kind of surface is titanium powder produced by reducing one mole of titanium dioxide with at least 4 moles of calcium halide (e.g. $CaCl_2$) and at least 9.6 moles of sodium at a temperature of about 800 to 900° C.

The coating of my compositions can be an alkali metal, that is, lithium, sodium, potassium, rubidium, caesium, or mixtures of these elements. Advantages may also be obtained by employing alkali metal-containing alloys such as mixtures of sodium and calcium; sodium, potassium and calcium; sodium, barium and calcium; and the like. When employing such mixtures I select a mixture possessing a melting point not substantially in excess of about 400° F. Alkaline earth metals, namely barium, calcium and strontium may also be used with some degree of success.

The additives of this invention are prepared most readily by agitating the finely divided metal to be coated with an alkali metal, or low melting alloy containing the same, at a temperature at which the coating material is in the molten state.

Generally speaking, the film substantially surrounding the metallic particles of my compositions should be from about 0.001 to about 0.1 micron in thickness. Coatings of approximately these thicknesses are obtainable by controlling both the relative amounts of the metals in question and the duration of mechanical agitation.

The following examples wherein all parts and percentages are by weight more fully illustrate typical methods of preparation.

Example I

The reaction equipment consists of a container equipped with stirring and heating means. To this container is added 200 parts of finely divided magnesium metal having an average particle size of about 100 microns. While maintaining an atmosphere of dry nitrogen gas throughout the system 10 parts of metallic sodium is added. After the temperature has been raised to the melting point of sodium (approximately 98° C.), the mixture is agitated at a speed of 1850 revolutions per minute for a period of 5 minutes. The reaction vessel is then allowed to cool to room temperature while agitating. The contents of the reaction vessel are emptied into a suitable container previously flushed with dry nitrogen gas. This container is then sealed from the atmosphere for storage purposes.

Example II

The procedure of Example I is repeated using 100 parts of boron having an average particle size of about 110 microns and 15 parts of metallic sodium.

Example III

The procedure of Example I is repeated except that 200 parts of powdered aluminum of an average size of about 95 microns is used as the material to be coated. In this procedure 12 parts of metallic sodium are added, melted and mechanically agitated therewith.

Example IV

To the reaction equipment of Example I is added 100 parts of finely divided titanium metal having an average particle size of about 85 microns. While maintaining the reaction equipment under an atmosphere of dry argon gas 12 parts of metallic potassium are introduced into the vessel. The temperature is then raised to approximately 65° C. and the mixture is then agitated for 5 minutes. After reducing the temperature to about 20° C. while agitating, the contents of the vessel are emptied into a container flushed with anhydrous argon gas. The container is then sealed.

Example V

The procedure of Example IV is repeated except that 10 parts of metallic sodium and a temperature of 100° C. are used.

Example VI

To the reaction equipment described in Example I is added 100 parts of magnesium powder possessing an average particle size of about 100 microns. Substantially anhydrous nitrogen gas is continuously passed through the system. Next is added 14 parts of a sodium-calcium mixture containing these elements in a ratio of 4 gram atoms of sodium per every gram atom of calcium. The temperature of this mixture is then raised to about 160° C. and maintained at this temperature while agitating for a period of 15 minutes. The material of this invention so formed is then stored in a sealed container filled with dry nitrogen gas.

The preceding examples are illustrative of the manner in which the compositions of matter of this invention are prepared. Additional modes of preparing the addition agents of this invention will become apparent to one skilled in the art.

FUEL COMPOSITIONS

My fuels comprise combustible liquid fuels containing suspensions of the addition agents described above. Suitable base fuels include hydrocarbon blends having an end point of up to about 650° F. and a heating value in the order of about 18,000 B.t.u./lb. Conventional gas turbine fuel, motor and aviation gasoline base stocks and the like serve as examples. If desired, recourse can be had to various mixtures of gasolines, gas oils, distillates such as kerosene, synthetic fuels such as those manufactured by the Fischer-Tropsch process, etc. Fuel blends meeting the specifications of JP-3, JP-4, JP-5, or like jet combustion fuels are preferred because of their availability and combustion characteristics.

The finished fuels of this invention are prepared by mixing appropriate quantities of my addition agents with suitable substantially anhydrous fuel base stocks. In general, it is preferable to employ from about 10 to about 60 percent by weight of my addition agents in jet combustion fuel. Deviations from these limits are sometimes desirable to take into account the variability of the unit weight of the additives of this invention. The following examples more specifically illustrate the methods of preparing my improved jet combustion fuels. All parts and percentages are by weight.

Example VII

To 6,130 parts of substantially anhydrous gas turbine engine fuel having a 10 percent evaporation point of 250° F. and an end point of 535° F., a specific gravity at 60° F. of 0.810, a freezing point of −85° F. and a heating value of 18,650 B.t.u./lb. is added 4,000 parts of sodium-coated magnesium suspendable prepared according to Example I. While agitating this mixture at approximately 2,000 r.p.m., approximately 40 parts of oleic acid is added and the agitation continued for 10 minutes. The finished fuel contains approximately 40 percent of polymetallic addition agent.

Example VIII

The procedure of Example VII is repeated except that 5,000 parts of finely divided boron coated with potassium is used as the addition agent. The particles of this addition agent range from about 65 to about 500 microns in size. The finished fuel contains approximately 46 percent of addition agent.

Example IX

To 3,000 parts of substantially anhydrous aviation gasoline of grade 100/130, having an end point of 330° F. is added 1,500 parts of sodium-coated aluminum prepared according to Example III. While agitating at 1800 r.p.m., 10 parts of aluminum stearate is added.

Example X

1,500 parts of the additive prepared according to Example IV is added to 6,000 parts of substantially anhydrous aviation gasoline of 115/145 grade. To this mixture while agitating at a temperature of 50° C. is added 30 parts of polyethylene.

The fuels prepared in accordance with the preceding illustrative examples are eminently suited for use as after-burner fuels. By way of example, it is found that when the fuel composition prepared according to Example VII is introduced into a supplemental fuel system of a typical turbo-jet aircraft and used in conjunction with a spark-ignited after-burner, that is, by injection and ignition of a supplemental fuel, the completeness of combustion as measured by the temperature of the gases leaving the after-burner or by the increase in thrust is materially improved compared to that obtained when jet fuel without an additive or jet fuel with a magnesium suspension not coated with sodium is used. Other advantages obtained by the use of the fuel compositions of this invention include:

(1) Greater and more rapid evolution of heat resulting in improved flame-spreading characteristics so that there is a greater amount of gas expansion per unit of engine volume with consequent increases in thrust.
(2) Easier anchoring of the flame front at the desired portion of the combustion zone thereby reducing the size and complexity of flame-holders or other baffles commonly used for this purpose.
(3) Elimination of flame blow-out.
(4) Marked reduction in rough combustion and the attendant problems associated with this problem such as excessive vibration tendencies which have been known to result in physical disintegration of the engine.
(5) Improved cold starting of jet propulsion devices, particularly ram-jet engines.
(6) Better and more effective use of elemental fuels which have the high combustion energies that are desirable but which are difficult to ignite and burn rapidly.

Another tangible advantage of my invention is that the above and other advantages are realized at a minimum of cost.

Although eminently suitable as booster fuels for use in conjunction with after-burners in turbo-jet aircraft, my fuel compositions find important utility as the source of power for ram-jet engines. In this instance, the more rapid and complete combustion resulting from the incorporation in the fuel of the compositions of matter of my invention assures a greater rate of power output than is obtainable by the employment of conventional fuels or such fuels containing dispersions of uncoated elements. Other applications of the addition agents and finished fuels of this invention will become apparent to those skilled in the art.

The fuel compositions of this invention can contain other additives, such as, corrosion inhibitors, antioxidants and the like. Also, dispersing agents can be used to advantage in my finished fuels. Thus, use can be made of such dispersing agents as higher fatty acids as described in U.S. Patent 2,394,608, alkali metal soaps of higher fatty acids adsorbed on finely divided carbon disclosed in U.S. 2,487,333, alkali metal salts of organic hydroperoxides per U.S. 2,487,334, metallic soaps such as aluminum stearate, activated clay, carboxylic acid esters of cyclic inner ethers of hexatol, activated bentonite, or the like. Although not absolutely essential such dispersing agents assure greater stability of the suspensions herein described. Amounts of these agents between about 0.1 and about 5 percent based on the total weight of the addition agent are satisfactory.

Gelling or stabilizing agents, such as polyethylene and other like polymers can also be employed. Such agents when present in my fuels in amounts up to about one or two percent by weight increase the viscosity of the fuel by a gelation mechanism thereby affording greater dispersion stability.

Having fully described the nature of the instant invention, the need therefor, and the best methods devised for carrying it out, I do not intend that my invention be limited except within the spirit and scope of the appended claims.

I claim:

1. In a method of operating a jet combustion engine, wherein a fuel is burned in a combustion chamber and the products of combustion are allowed to escape through a jet, thereby producing a driving force, the improvement which comprises injecting into the chamber a fuel which consists essentially of a combustible liquid hydrocarbon fuel having an end point of up to about 650° F. and a heating value of about 18,000 B.t.u. per pound containing about 10 to about 60 percent by weight of a finely divided core element having a heat of combustion of at least 8000 B.t.u. per pound and at least 2000 B.t.u. per pound of air required for complete combustion and a melting point greater than about 400° F., said element being selected from the group consisting of aluminum, beryllium, magnesium, silicon, titanium and boron, in intimate contact with a thin adhering film of a coating of a light metal selected from the class of alkali and alkali-alkaline earth mixtures, said finely divided core element having a particle size of from about 10 to about 1000 microns and said coating material being deposited in a film having a thickness of from about 0.001 to about 0.1 micron and igniting the fuel therein.

2. In a method of operating a gas turbine jet combustion engine wherein a fuel is burned in a combustion chamber, and the products of combustion containing residual oxygen are allowed to pass through a turbine, the improvement which comprises injecting into a second chamber rearwardly from the gas turbine a supplemental fuel which consists essentially of a combustible liquid hydrocarbon fuel having an end point of about 650° F. and a heating value of about 18,000 B.t.u. per pound containing from about 10 to about 60 percent by weight of a finely divided core element having a heat of combustion of at least 8000 B.t.u. per pound and at least 2000 B.t.u. per pound of air required for complete combustion and a melting point greater than about 400° F., said element being selected from the group consisting of aluminum, beryllium, magnesium, silicon, titanium and boron, in intimate contact with a thin adhering film of a coating of a light metal selected from the class of alkali and alkali-alkaline earth mixtures, said finely divided core element having a particle size of from about 10 to about 1000 microns and said coating material being deposited in a film having a thickness from about 0.001 to about 0.1 micron and igniting the supplemental fuel therein.

3. A composition of matter particularly adapted as an additive for jet combustion after-burner fuel which is composed of a suspendable consisting essentially of a finely divided core element having a heat of combustion of at least 8000 B.t.u. per pound and at least 2000 B.t.u. per pound of air required for complete combustion and a melting point greater than about 400° F., said element being selected from the group consisting of aluminum, beryllium, magnesium, silicon, titanium and boron, in intimate contact with a thin adhering film of a coating of a light metal selected from the class of alkali and alkali-alkaline earth mixtures, said finely divided core element having a particle size of from about 10 to about 1000 microns and said coating material being deposited in a film having a thickness of from about 0.001 to about 0.1 micron.

4. The composition of claim 3 in which said core element is aluminum.

5. The composition of claim 3 in which said core element is boron.

6. The composition of claim 3 in which said core element is magnesium.

7. A fuel composition adapted for use as jet combustion after-burner fuel which consists essentially of a combustible liquid hydrocarbon fuel having an end point of up to about 650° F. and a heating value of about 18,000 B.t.u. per pound containing dispersed therein from about 10 to about 60 percent by weight of the composition of claim 9.

8. A fuel composition adapted for use as jet combustion after-burner fuel which consists essentially of a combustible liquid hydrocarbon fuel having an end point of up to about 650° F. and a heating value of about 18,000 B.t.u. per pound containing about 10 to about 60 percent by weight of a suspendable consisting essentially of a finely divided core element selected from the group consisting of aluminum, beryllium, silicon, titanium, boron and magnesium to which has been applied a coating of an alkali metal.

9. The composition of claim 8 wherein said core element is aluminum.

10. The composition of claim 8 wherein said core element is boron.

11. The composition of claim 8 wherein said core element is magnesium.

12. A fuel composition adapted for use as jet combustion after-burner fuel which consists essentially of a combustible liquid fuel having an end point of up to about 650° F. and a heating value of about 18,000 B.t.u. per pound containing dispersed therein from about 10 to about 60 percent by weight of a suspendable consisting essentially of finely divided magnesium coated with sodium.

13. The composition of claim 3 in which said suspendable is finely divided magnesium coated with a thin film of sodium.

References Cited in the file of this patent

UNITED STATES PATENTS

2,477,549	Van Loenen	July 26, 1949
2,573,471	Malina et al.	Oct. 30, 1951

UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,968,917 January 24, 1961

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It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 63, for the claim reference numeral "9" read -- 3 --.

Signed and sealed this 15th day of August 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
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DAVID L. LADD
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