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3,113,894

THIXOTROPIC HETEROGENEOUS MONO-
PROPELLANT COMPOSITIONSJoe M. Burton, Alexandria, Va., assignor to Atlantic
Research Corporation, Alexandria, Va., a corporation
of VirginiaNo Drawing. Filed June 27, 1962, Ser. No. 205,564
27 Claims. (Cl. 149-19)

This invention relates to new heterogeneous monopropellant compositions capable of generating gases containing high available energy for such purposes as producing thrust or power, heat energy or gas pressure. More specifically, it relates to plastic, extrudable, shape-retaining monopropellant compositions of high density comprising a finely-divided solid oxidizer dispersed in a continuous matrix of a viscous liquid fuel. This application is a continuation-in-part of application S.N. 791,486 to Joe M. Burton, filed February 5, 1959, now abandoned.

The term monopropellant refers to a composition which is substantially self-sufficient with regard to its oxidant requirements as distinguished from bipropellants where the fuel is maintained separately from the oxidizer source until admixture at the point of combustion. The term heterogeneous refers to the two-phase solid oxidizer-liquid matrix system.

A heterogeneous plastic monopropellant, which can be extruded under pressure into a combustion chamber in the form of a continuously advancing, shape-retaining cohesive mass or column and there ignited so that the leading face of the advancing mass burns to generate hot, high pressure combustion gases, combines many of the advantages of both liquid and solid propellants and eliminates many of their disadvantages. Such semi-solid monopropellants are disclosed in co-pending Scurlock application S.N. 694,897, filed November 6, 1957, now Patent No. 3,095,334, issued June 25, 1963.

For uniform burning of such plastic, heterogeneous monopropellants, it is essential that the solid oxidizer and any other solid component, such as a finely-divided metal fuel, remain uniformly and stably dispersed. It is also desirable that the composition be thixotropic, namely, tend, above a certain minimum stress, to increase in fluidity with increasing stress and to decrease in fluidity with decreasing stress. To obtain the desired phase stability and thixotropy, it has generally been necessary to dissolve a gelling agent in the liquid matrix. This has the practical disadvantage of requiring an additional gelling step, frequently with concomitant heating for solution of the gelling agent. Syneresis and irreversible destruction of the gel structure under conditions, such as freezing, also limit the range of usefulness of many of the gelled compositions.

The object of this invention is to provide stable, high density, heterogeneous, extrudable monopropellant compositions comprising finely-divided solid oxidizer dispersed in a viscous liquid polymer for extrusion as cohesive, shape-retaining, continuously advancing masses into a combustion chamber where they are burned to generate high energy gases for developing thrust or power or for providing heat or gas pressure.

Another object is to provide such heterogeneous compositions which possess the requisite plasticity, cohesiveness, tensile strength, and freedom from phase separation without requiring the addition of a gelling agent.

Other objects and advantages will become obvious from the following detailed description.

I have found that a liquid fuel vehicle comprising, at least in part, a viscous liquid organic polymer, and having a minimum viscosity of about 400 centipoises at 77° F., preferably a minimum of about 1500, will hold the

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finely-divided solid oxidizer and other solid components, such as a finely-divided metal fuel, in stable, uniform dispersion without separation for indefinitely long periods of time and will, furthermore, impart excellent thixotropic properties to the plastic propellant mixture without requiring the addition of a gelling agent.

My new monopropellant compositions accordingly comprise stable dispersions of finely-divided, insoluble, solid oxidizer in a continuous, non-volatile, liquid fuel matrix comprising a viscous, liquid, organic polymer which can be oxidized to form hot combustion gases. The compositions can also contain dispersed therein, a finely-divided metal as an additional fuel component. Admixture with the liquid of adequate amounts of the finely-divided solids results in plastic, extrudable monopropellant compositions of sufficiently high cohesive strength to retain a formed shape while being capable of continuous flow at ordinary to reduced temperature. The plastic compositions possess characteristics of non-Newtonian liquids, namely yield to flow only under a finite stress.

These high density, plastic monopropellants are particularly adapted to being fed at ambient temperatures under pressure from a storage chamber into a combustion chamber in the form of any desired continuous coherent shape, such as a column, strip, or the like, with combustion taking place on the leading face of the advancing material. Such a plastic, two-phase system, in which the solid oxidizer is uniformly dispersed in a continuous liquid matrix, ensures smooth coherent flow and, very importantly, a constant mass burning rate for a given area of exposed burning surface. In this respect, the burning properties are similar to those of a solid propellant grain.

The shape-retentive cohesiveness of the monopropellant material should preferably be sufficiently high so that it possesses a minimum tensile strength of about 0.01 p.s.i. and preferably about 0.03 p.s.i. or higher. The material should, however, be capable of yielding to continuous flow at ordinary to reduced temperatures under stress or pressure. The use of excessively high pressures to produce the requisite flow is undesirable for practical reasons, although available pressure-producing devices will, of course, vary with particular applications. The maximum shear stress at a wall, required to initiate and sustain flow of the composition at ordinary or ambient temperatures, is preferably not higher than about 1 p.s.i. with a maximum of about 10 p.s.i.

The physical properties of the extrudable, plastic mix, such as cohesiveness, tensile strength, pressure required to produce flow, and stability of the two-phase system, are largely determined by such factors as the viscosity of the liquid fuel matrix and the concentration and particle size of the solid disperse phase. The afore listed properties can be increased or decreased in degree by increasing or decreasing the viscosity of the liquid matrix, by increasing or decreasing the loading density of dispersed solids, or by a combination of both factors. Since the loading density of the solids, namely the concentration of solid oxidizer or oxidizer and finely-divided metal fuel, can be varied only to a limited extent for a particular application, because of the required gas-generation properties, the viscosity of the liquid matrix becomes a highly advantageous, easily manipulated means for tailoring the physical properties of the heterogeneous monopropellant for any given required component formulation.

At high solids loading densities, e.g. about 75% by weight or more, a liquid fuel matrix having a relatively low viscosity (but at least about 400 centipoises and preferably at least 1500), is adequate to provide the requisite stability against separation and the other essential physical properties. The lower viscosity of the liquid within the permissible range also facilitates mixing and uniform

dispersion of the high concentration of solids in the liquid vehicle. Where fuel-rich propellant compositions are desired for applications, such as gas turbines, requiring relatively low combustion temperatures, the amount of solid oxidizer can be reduced to the desired level while maintaining the requisite dispersion stability, cohesiveness and other desired physical characteristics, by employing a liquid fuel matrix of high viscosity.

Any desired viscosity can be obtained by selecting a liquid polymer having the proper viscosity, by mixing the same or different liquid polymers of different viscosities in proper proportions, or by diluting a liquid polymer of high viscosity with any miscible, substantially non-viscous, non-volatile liquid fuel, namely a liquid which burns to form hot combustion gases and has a viscosity less than the desired viscosity of the liquid matrix as a whole. Thus the viscosity of such a liquid diluent can be substantially less than 400 centipoises.

The polymer forming the liquid matrix, in whole or in part, can be any organic polymer which, though viscous, is sufficiently mobile to flow at ordinary temperatures and which has a minimum viscosity at 77° F. of about 400 centipoises, preferably about 1500. Such liquid polymers are generally of relatively low molecular weight as compared with solid polymers, the particular molecular weight varying with the particular polymer. The polymer is preferably one which does not further polymerize during storage with resulting increase in viscosity or solidification or one which can be stabilized against further polymerization by the addition of a suitable inhibiting agent. Examples of suitable liquid polymers for my purpose include the relatively low molecular weight liquid hydrocarbon polymers, such as polyethylene, polypropylene, polyisobutylene, polyisoprene, and liquid rubber made by partial thermal depolymerization of natural or synthetic rubber; the low molecular weight siloxanes, such as methyl siloxane, phenylsiloxane and methylphenyl siloxane; liquid alkyd polyesters, such as the polyethylene oxide or polypropylene oxide esters of a dibasic acid, such as adipic, sebacic, succinic, maleic, phthalic, terephthalic and isophthalic acid; liquid acrylic and methacrylic acid esters, such as polymethyl methacrylate; high molecular weight, viscous polydiols, such as those made from polyethylene oxide, polypropylene oxide, and polytetrahydrofuran; liquid epoxy polymers; liquid phenolic polymers, such as polyphenol-formaldehyde; and many others.

The liquid polymer can be selected for its gas-generating and oxygen-demand properties in accordance with the specific requirements for the particular propellant use. In some cases, for example, it may be desirable to employ a polymer, such as a polyester or siloxane, in which the combined oxygen, though not available for further oxidation, reduces the stoichiometric oxidizer requirement for the molecule as a whole.

As aforementioned, the viscosity of the liquid fuel matrix can be tailored for any specific formulation by combining liquid polymers of different viscosity. The polymers can be chemically the same but of different molecular weight and, therefore, of different viscosity. Mixtures of chemically different liquid polymers of different viscosity are also entirely suitable.

In some cases, it may be expedient to dilute a highly viscous liquid polymer with sufficient non-volatile, substantially non-viscous, miscible liquid fuel to produce a liquid matrix of the particular desired viscosity. This not only broadens the range of available fuel-component formulations but also can be employed as a means for reducing the stockiness which is characteristic of some of the liquid polymers.

The non-volatile, non-viscous, liquid fuel component can be an inert organic compound, namely a compound which is combustible to produce gaseous combustion products but which requires an external oxidizer for oxidation. It can, however, and often preferably does, con-

tain combined oxygen which is not available to any appreciable extent for further oxidation, such as oxygen which is linked to a C, Si, S, or P atom in the molecule. Such inert liquid fuels have the advantage, important in some applications, of reducing stoichiometric oxygen requirements, and, where the oxygen is linked to carbon in the molecule, of reducing soot formation.

Examples of suitable inert, non-volatile, substantially non-viscous, organic liquid fuels include hydrocarbons, e.g., triethyl benzene, dodecane and the like; compounds containing some oxygen linked to a carbon atom, such as esters, e.g. dimethyl maleate, diethyl phthalate, dibutyl oxalate, dibutyl sebacate, dioctyl adipate, etc.; alcohols, e.g., benzyl alcohol, ethylene glycol, triethylene glycol, etc.; ethers, e.g., methyl α -naphthyl ether; ketones, e.g., benzyl methyl ketone, phenyl o-tolyl ketone, isophorone; acids, e.g., 2-ethylhexoic acid, caproic acid, n-heptylic acid, etc.; aldehydes, e.g., cinnamaldehyde; nitrogen-containing organic compounds such as amines, e.g., N-ethyl-aniline, tri-n-butylamine, diethyl aniline; nitriles, e.g., caprinitrile; phosphorus-containing compounds, e.g., triethyl phosphate; sulfur-containing compounds, e.g., diethyl sulfate, and many others. These organic liquid fuels have viscosities which are substantially less than 400 centipoises at 77° F.

Non-volatile, substantially non-viscous liquid fuels, which are self-oxidant, namely contain combined oxygen or other element, such as chlorine or fluorine, available for oxidation of other components of the molecule, can also be employed as a viscosity-adjusting diluent alone or in combination with a non-viscous inert liquid fuel. Such an active liquid component has the advantages of improving oxygen balance of the propellant mixture and making stoichiometric oxygen levels more easily obtainable, since it functions as a fluid vehicle for the solid oxidizer and, at the same time, reduces the total amount of solid oxidizer required for combustion of the reduced proportion of inert liquid polymer or liquid polymer and non-viscous inert liquid fuel. The use of an active, non-viscous, liquid diluent is particularly advantageous with inert liquids of high oxygen demand such as hydrocarbon polymers or with added finely-divided metal fuels.

Examples of suitable, non-volatile, substantially non-viscous, self-oxidant liquids which have viscosities less than 400 centipoises at 77° F. and which can be satisfactorily used include nitroglycerine, diethylene glycol dinitrate, pentaerithritol trinitrate, and 1,2,4-butanetriol trinitrate. It should be noted that the inert liquid polymer phlegmatizes these sensitive liquids so that the heterogeneous monopropellant mixes containing such active liquid components are, nevertheless, sufficiently insensitive to heat and shock.

The amount of substantially non-viscous liquid fuel component is not critical and is determined by the viscosity of the liquid polymer and the desired viscosity of the liquid fuel matrix. Where, for a particular application, a substantial amount of a particular non-viscous liquid, such as an oxygen-containing inert or active compound, is desired, excessive reduction of liquid matrix viscosity can be avoided by using a liquid polymer of sufficiently high viscosity to raise the viscosity of the liquid mixture to the desired level.

It is essential that the liquid fuel be non-volatile to ensure extended shelf-life and storageability even at relatively high environmental temperatures without loss of the liquid component by vaporization. This is necessary not only to maintain the predesigned combustion characteristics of the monopropellant but also to retain its desired physical characteristics. Vaporization of sufficient liquid fuel to leave a solid, granular mass would make the monopropellant unfit for the desired mode of use. The liquid polymers are, as a class, characterized by the requisite non-volatility, so that discretion on this point must be exercised only with regard to the non-viscous liquid diluent, if used. Maximum vapor pressure of such

non-viscous diluents is preferably not more than about 25 mm. Hg at 100° C.

The amount of liquid fuel vehicle in the composition is critical only insofar as an adequate amount must be present to provide a continuous matrix in which the solid phase is dispersed. This will vary to some extent with the particular solids dispersed, their shape, and degree of subdivision, and can readily be determined by routine test formulation. The minimum amount of liquid required generally is about 8%, usually about 10% by weight. Beyond the requisite minimum any desired proportion of liquid fuel to dispersed solid can be employed, depending on the desired combustion properties, since the desired cohesive, shape-retentive properties can be obtained by adjusting the viscosity of the fluid matrix.

The solid oxidizer can be any suitable, active oxidizing agent which yields oxygen readily for combustion of the fuel and which is insoluble in the liquid fuel vehicle. Suitable oxidizers include the inorganic oxidizing salts, such as ammonium, sodium, potassium and lithium perchlorate or nitrate, metal peroxides such as barium peroxide and the like. The solid oxidizer should be finely divided, preferably with a maximum particle size of about 300 to 600 microns, to ensure stable, uniform dispersion of the oxidizer in the liquid fuel, so that it will not separate or sediment despite lengthy storage periods, although some somewhat larger particles, e.g. up to about 1000 microns, can be maintained in the viscous fuel matrix without separation. Optimum particle size is to a considerable extent determined by the viscosity of the particular liquid matrix and can readily be determined with routine testing by those skilled in the art. Although not essential, a size dispersion of the particles is often desirable because of the improved packing effect obtained in terms of increased amounts of solids which can be incorporated. Improved loading densities are obtained with oxidizer particles so distributed in size that the minimum ratio of size of the smallest to the largest is about 1:2 and preferably about 1:10.

The amount of solid oxidizer incorporated varies, of course, with the particular kind and concentration of fuel components in the formulation, the particular oxidizer, and the specific requirements for a given use, in terms, for example, of required heat release and rate of gas generation, and can readily be computed by those skilled in the art. The upper limit of oxidizer addition is set only by the requirement that it be dispersed in a continuous matrix of the liquid vehicle. Since the liquid vehicle can be loaded with as high as 80 to 92% of finely-divided solids, stoichiometric oxidizer levels with respect to the inert liquid or inert liquid and metal fuel components can generally be obtained where desired, with increased latitude in some cases being provided, if desired,

by addition of a non-viscous, self-oxidant, viscosity-adjusting diluent. As aforementioned, in some applications, stoichiometric oxidation levels may not be necessary or even desirable and the amount of oxidizer can be correspondingly reduced, it being essential only that adequate oxidizer be present to provide for active combustion of the fuel components and an adequate degree of gas generation for the particular use.

Finely-divided, solid metal powders, such as Al, Mg, Zr, B, Be, Ti, and Si, can be introduced into the monopropellant compositions as an additional fuel component along with the liquid fuel. Such metal powders possess the advantages both of increasing density and improving specific impulse of the monopropellant because of their high heats of combustion. The metal particles should preferably be within a size range of about 0.25 to 50 microns. The amount of such metal fuel added is not critical but is determined largely by the specific use and the requisite physical characteristics of the composition as aforedescribed. Even very minor additions, e.g. 1 or 2% by weight, increase density and heat of combustion. In general, the metal will constitute a minor proportion by weight of the propellant composition, maximum limits being set by the need to avoid granulation of the mixture and an excessive deficiency in amount of oxidizer.

Other additives which can be incorporated into the monopropellant compositions include, for example, burning rate catalysts, such as ammonium dichromate, copper chromite and ferric ferrocyanide; coolants for reducing the temperatures of the generated gases where necessary, as in the case of some turbine applications, such as monobasic ammonium phosphate, barbituric acid and ammonium oxalate; and the like.

The heterogeneous monopropellants are prepared simply by mixing the components in any suitable mixing apparatus. In addition to their simplicity, manufacturing operations are relatively non-hazardous because of the low sensitivity of the components. Even where a portion of the liquid fuel is a highly active compound, such as nitroglycerine, dilution with the inert liquid polymer greatly reduces shock- and impact-sensitivity.

Table I summarizes a variety of propellant formulations in which liquid polyisobutylene of different molecular weights and viscosities was employed as the viscous liquid fuel matrix. Dibutyl phthalate and a low viscosity silicone oil were employed in certain instances to adjust the viscosity and to reduce stickiness. Powdered Al was introduced into some of the formulations to increase specific impulse. Copper chromite was included in certain of the compositions as a catalyst to increase burning rate and reduce pressure exponent, its marked effect being clearly shown by comparison of #24 and 25 and #23 and 26. Ballistic data are given where available.

Table I

Composition (parts by weight)	#11	#12	#13	#14	#15	#16	#17	#18	#19	#20	#21	#22	#23	#24	#25	#26
Ammonium perchlorate ¹ (6900 r.p.m., 2 μ grind)	39.27	-----	42.67	41.80	-----	-----	50.00	50.00	-----	-----	-----	-----	-----	42.56	42.14	-----
Ammonium perchlorate ² (unground)	19.63	-----	21.33	20.90	-----	-----	25.00	25.00	-----	-----	-----	-----	-----	21.28	21.06	-----
Ammonium perchlorate ³ (14,000 r.p.m. grind)	-----	75.00	-----	-----	75.00	75.00	-----	-----	75.00	75.00	75.00	75.00	75.00	-----	-----	75.00
Polyisobutylene, ⁴ mol. wt. about 600	19.75	25.00	15.00	11.80	15.00	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Polyisobutylene, ⁴ mol. wt., 8700-10,000	-----	-----	-----	-----	10.00	18.75	17.50	15.00	15.00	10.00	9.60	10.00	7.50	-----	-----	7.50
Polyisobutylene, ⁴ mol. wt., 840	-----	-----	-----	-----	-----	6.25	7.50	10.00	10.00	15.00	14.40	15.00	11.25	14.96	14.81	11.25
Dibutyl phthalate	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.00	4.50	6.25	-----	-----	6.25
Silicone oil, 500 cp. ⁷	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	20.95	20.74	-----
Aluminum ⁸	21.10	-----	21.00	25.50	-----	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	-----	1.00	-----
Copper chromite	-----	1.00	-----	-----	1.00	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.25	0.25	-----
Wetting agent	0.75	-----	0.75	0.75	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Ballistic Data at 70° F. and 1000 p.s.i.:	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Burning rate (in./sec.)	-----	-----	-----	-----	0.70	-----	-----	-----	-----	0.65	-----	-----	0.63	0.52	0.76	0.42
Pressure exponent	-----	-----	-----	-----	0.59	-----	-----	-----	-----	0.63	-----	-----	0.57	0.68	0.62	0.76

¹ 24 micron weight average size. ² 194 micron weight average size. ³ 51.4 micron weight average size. ⁴ Viscosity about 300° centipoises at 100° F. ⁵ Viscosity about 1,000,000 centipoises at 100° F. ⁶ Viscosity about 7000 centipoises at 100° F. ⁷ Viscosity about 500 centipoises at 100° F. ⁸ 8 Micron weight average size.

Table II summarizes two plastic monopropellant formulations employing respectively a liquid polydimethylsiloxane and a polyester condensation product of adipic acid and a glycol.

Table II

Composition (parts by weight)	#27	#28
Polydimethylsiloxane ¹ -----	18.7	29.8
Polyester ² -----	88.9	46.5
Ammonium perchlorate (6500 r.p.m. 2m grind)-----	19.5	23.2
Ammonium perchlorate (unground)-----	22.4	0.5
Aluminum (8 micron wt.-av.-size)-----	0.5	0.5
Copper chromite-----	1.10	0.34
Ballistic Data at 70° F. and 1000 p.s.i.:-----	0.41	0.35
Burning rate (in./sec.)-----	280	265
Pressure exponent-----		
Autoignition temperature, ° C-----		

¹ Viscosity 400 centipoises at 77° F.

² Viscosity about 50,000 centipoises at 77° F.

Although this invention has been described with reference to illustrative embodiments thereof, it will be apparent to those skilled in the art that the principles of this invention can be embodied in other forms but within the scope of the claims.

I claim:

1. In a heterogeneous monopropellant composition consisting essentially of finely-divided, solid, insoluble, inorganic oxidizer, dispersed in a continuous, oxidizable, organic fuel matrix, and which burns to form gaseous combustion products, said fuel matrix being a mobile liquid which forms at least about 8% by weight of said composition, and comprises one or more organic liquid components, all of which contain molecularly-combined carbon and hydrogen and have a maximum vapor pressure of about 25 mm. Hg at 100° C., and at least one of which is an inert compound requiring an external oxidizer for combustion, said inorganic oxidizer being present in amount sufficient to maintain active combustion of the inert organic fuel compound, the improvement in which said liquid fuel matrix has a minimum viscosity of about 400 centipoises at 77° F., and consists essentially of a synthetic liquid organic polymer which has a minimum viscosity of about 400 centipoises at 77° F., is sufficiently mobile to flow at ordinary temperatures, and does not further polymerize substantially in said monopropellant composition during storage, said monopropellant being an extrudable, thixotropic composition which requires a finite stress to produce flow, is indefinitely capable, after storage, of continuous flow at ambient temperatures under a maximum shear stress at a wall of about 10 p.s.i., and has a minimum tensile strength of about 0.01 p.s.i., said viscous liquid polymer serving to impart thixotropic properties to the monopropellant composition and to hold the dispersed solids in stable dispersion.

2. The monopropellant composition of claim 1 in which the synthetic liquid organic polymer is selected from the group consisting of hydrocarbon polymers, siloxanes, alkyl polyesters, acrylic and methacrylic acid esters, polydiols, epoxy polymers and phenolic polymers.

3. The monopropellant composition of claim 1 in which the synthetic liquid organic polymer component comprises a mixture of synthetic liquid organic polymers having different viscosities, the least viscous polymer having a minimum viscosity of about 400 centipoises at 77° F.

4. The monopropellant composition of claim 1 in which the synthetic liquid organic polymer has a viscosity which is substantially higher than about 400 centipoises at 77° F., and higher than the desired viscosity of the liquid fuel mixture, and is admixed with an oxidizable non-viscous organic liquid fuel which has a viscosity substantially less than 400 centipoises at 77° F., said non-viscous liquid being present in an amount which reduces the viscosity of the liquid fuel to the desired viscosity, the minimum viscosity of the mixture being about 400 centipoises at

77° F., and thereby providing a means for controllably adjusting the viscosity of the liquid fuel matrix.

5. The monopropellant composition of claim 1 which contains, in addition, a minor proportion by weight of a finely-divided metal fuel dispersed in the continuous matrix of the organic liquid fuel.

6. The monopropellant composition of claim 1 in which the minimum tensile strength is about 0.03 p.s.i.

7. The monopropellant composition of claim 6 in which the synthetic liquid organic polymer is selected from the group consisting of hydrocarbon polymers, siloxanes, alkyl polyesters, acrylic and methacrylic acid esters, polydiols, epoxy polymers and phenolic polymers.

8. The monopropellant composition of claim 6 in which the synthetic liquid organic polymer component comprises a mixture of synthetic liquid organic polymers having different viscosities, the least viscous polymer having a minimum viscosity of about 400 centipoises at 77° F.

9. The monopropellant composition of claim 6 in which the synthetic liquid organic polymer has a viscosity which is substantially higher than about 400 centipoises at 77° F., and higher than the desired viscosity of the liquid fuel mixture, and is admixed with an oxidizable non-viscous organic liquid fuel which has a viscosity substantially less than 400 centipoises at 77° F., said non-viscous liquid being present in an amount which reduces the viscosity of the liquid fuel to the desired viscosity, the minimum viscosity of the mixture being about 400 centipoises at 77° F., and thereby providing a means for controllably adjusting the viscosity of the liquid fuel matrix.

10. The monopropellant composition of claim 9 in which the synthetic liquid polymer is an inert compound which requires an external oxidizer for combustion, and the non-viscous organic fuel component is an active compound which contains combined oxygen available for oxidation of other molecularly-combined components of said active compound to form gaseous combustion products.

11. The monopropellant composition of claim 6 in which the liquid fuel matrix and the synthetic liquid organic polymer component have minimum viscosities of about 1500 centipoises at 77° F.

12. The monopropellant composition of claim 7 in which the liquid fuel matrix and the synthetic liquid organic polymer component have minimum viscosities of about 1500 centipoises at 77° F.

13. The monopropellant composition of claim 8 in which the liquid fuel matrix and the mixture of liquid organic polymers have minimum viscosities of about 1500 centipoises at 77° F.

14. The monopropellant composition of claim 9 in which the liquid organic polymer has a viscosity substantially higher than about 1500 centipoises at 77° F. and the non-viscous organic liquid is present in an amount which reduces the viscosity of the liquid fuel matrix to a minimum of about 1500 centipoises at 77° F.

15. The monopropellant composition of claim 10 in which the liquid organic polymer has a viscosity substantially higher than about 1500 centipoises at 77° F. and the non-viscous organic liquid is present in an amount which reduces the viscosity of the liquid fuel matrix to a minimum of about 1500 centipoises at 77° F.

16. The monopropellant composition of claim 7 in which the synthetic liquid organic polymer is a hydrocarbon polymer.

17. The monopropellant composition of claim 12 in which the synthetic liquid organic polymer is a hydrocarbon polymer.

18. The monopropellant composition of claim 17 in which the hydrocarbon polymer is liquid polyisobutylene.

19. The monopropellant composition of claim 18 in which the solid oxidizer is finely-divided ammonium perchlorate.

20. The monopropellant composition of claim 12 in which the synthetic liquid organic polymer is a polyester.

21. The monopropellant composition of claim 12 in which the synthetic liquid organic polymer is a siloxane.

22. The monopropellant composition of claim 6 which contains, in addition, a minor proportion by weight of a finely-divided metal fuel dispersed in the continuous matrix of the organic liquid fuel.

23. The monopropellant composition of claim 7 which contains, in addition, a minor proportion by weight of a finely-divided metal fuel dispersed in the continuous matrix of the organic liquid fuel.

24. The monopropellant composition of claim 9 in which the synthetic liquid organic polymer is selected from a group consisting of hydrocarbon polymers, siloxanes, alkyd polyesters, acrylic and methacrylic acid esters, polydiols, epoxy polymers and phenolic polymers.

25. The monopropellant composition of claim 24 which contains, in addition, a minor proportion by weight of finely-divided metal fuel dispersed in the continuous matrix of the organic liquid fuel.

26. The monopropellant composition of claim 6 in which the solid oxidizer comprises particles distributed in size such that minimum size ratio of the largest and the smallest particles is about 2 to 1.

27. The monopropellant composition of claim 7 in which the solid oxidizer comprises particles distributed in size such that minimum size ratio of the largest and the smallest particles is about 2 to 1.

No references cited.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,113,894

December 10, 1963

Joe M. Burton

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 3, lines 20 and 21, for "viscose" read -- viscous --; column 4, line 14, for "triethyene" read -- triethylene --; column 6, line 35, for "siutable" read -- suitable --; columns 5 and 6, Table I, footnote 4, for "300°" read -- 3000 --.

Signed and sealed this 28th day of July 1964.

(SEAL)

Attest:

ESTON G. JOHNSON
Attesting Officer

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