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COMPOSITE HIGH ENERGY SOLID ROCKET PROPELLANTS AND PROCESS FOR SAME

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ABSTRACT OF THE DISCLOSURE

The invention relates to high energy solid rocket propellants comprising an elastomeric organic fuel bindner, a finely divided solid inorganic oxidizing agent, and an additive mixture of finely divided solid combustible high energy substances, one substance more readily ignitable than the other.

BACKGROUND OF THE INVENTION

This invention relates to high energy rocket propellants and the process by which they are employed in the rocket engine for rocket powered flight. This application is a continuation-in-part of my application Ser. No. 404,896 filed Oct. 19, 1964 and also replaces application Ser. No. 485,677 in which the application but not the invention has been abandoned.

The prior art relates mainly to the use of combustible polymeric organic solid fuel binders containing various high energy finely divided solid additives and solid oxidizing agents, disclosed in a generalized basis. The present invention relates to the use of specific combinations of high energy fuels which are cooperative in improving both the effectiveness and utility of the rocket as set forth below.

SUMMARY AND BRIEF DESCRIPTION OF THE INVENTION

The present invention relates particularly to solid propellants and solid propellant rocket systems in which both the fuel binder and an addition of selected high energy finely divided rocket fuel additives as well as the oxidizer are employed in solid form in the rocket engine system.

The fuel binder is combustible with elastomeric properties in an organic polymeric semi-solid to solid substance and contains dispersed therein specific mixtures of finely divided high energy solid fuel additives which are cooperative in their action and effect, and a finely divided solid oxidizer in sufficient amounts to oxidize both the fuel binder and the high energy fuel additives. The latter which always consists of more than one additive are preferably mixed with each other and are separately mixed with a portion of the bindner and are later mixed with the remaining portion of the bindner containing the finely divided solid oxidizer dispersed therein.

The solid fuel which I employ in my invention is actually a unique composite but stable mixture which is made up by suspending combustible specific mixtures of finely divided solid high energy additives which possess high energy as well as other unique characteristics and which are incorporated in specific and novel combinations in a selected solid fuel binder having elastomeric physical properties and preferably of the class of polymeric hydrocarbons and related elastomers including synthetic rubbers as well as natural rubbers. I may also employ other nonequivalent combustible organic compounds which combine the physical properties of these substances such as elasticity and tensile strength with the chemical property of combustibility in the presence of a solid oxidizing agent which is also a requirement.

The finely divided solid high energy additives previously disclosed by me and shown below are primarily in the hydride class which are admixed in various combinations with the following group of substances: (1)(a) Boron and/or beryllium (b) Nitrides of boron and beryllium. Both of these groups are mixed with the hydrides shown below. (2) Nitrides of boron and beryllium admixed with elementary magnesium. (3) Magnesium and aluminum nitride admixed with a hydride or elementary magnesium. Group (1)(a) is the preferred group. All of these are non-equivalent. I may also employ nonequivalently aluminum diboride in admixture either with one of these hydrides or magnesium.

In use all of these finely divided high energy fuel additives are dispersed in the combustible elastomeric organic polymer fuel bindner material and are mixed separately from the finely divided solid oxidizing substance which is also separately mixed with the fuel binder and the separate mixtures are then combined. The resulting rocket propellant mixture is then stable both physically and chemically, and posses highly superior rocket fuel properties. The heavier high energy additives, e.g., boron, beryllium and their nitrides, etc. are generally present in major proportions relative to the hydrides and other additives which are admixed with them to facilitate ignition of the boron, beryllium and the like. The hydrides, etc., are thus present generally in proportion of less than 50% of the mixture of high energy additives down to about 1% to 5% of the same. In all of these cases the objective is to facilitate ignition of the boron, beryllium and their nitrides and the other compounds or elements shown in the group above.

The finely divided solid high energy additives in the hydride class are mixed with the other high energy solid compounds referred to above, namely boron and beryllium and their nitrides and the other substances referred, is dispersed in the combustible elastomeric organic polymer material in a manner discussed above and to be more fully described below. The finely divided solid high energy additives which I employ include lithium hydride (LiH), lithium aluminum hydride ($LiAlH_4$); lithium borohydride ($LiBH_4$); beryllium hydride (BeH_2); decaborane ($B_{10}H_{14}$); magnesium hydride (MgH_2); magnesium borohydride ($Mg(BH_4)_2$); aluminum hydride (AlH_3); and combinations thereof such as magnesium aluminum hydride ($Mg.(AlH_4)_2$. It is noted that all of these compounds are hydrides and are solids which have been found to have very much higher energy values as rocket fuels than the polymeric organic fuel binder in which they are dispersed and which together with the other additives and with the finely divided solid oxidizers comprise my improved high energy solid rocket propellants.

The hydrides may be employed in amounts of from about 5% to about 50% more or less of the high energy additives depending on whether they serve the function primarily to ignite the more stable boron and beryllium and their nitrides or whether they are expected to contribute a larger proportion of the total energy to the fuel mixture. In any event a balance is preserved with regard to stability of the mixture, the total content of the latter and facilitating the operation of the rocket.

The nitrides, particularly of beryllium are reactive with water and the coating of the same with special polymers or mixing high energy fuel mixtures with the elastomeric fuel binder separately which is the normal procedure as described below serves the additional purpose of preventing this undesirable effect.

It is emphasized that the hydrides and mixtures of high energy fuel additives containing them are very active chemically and are not mixed directly with the oxidizers but both should be mixed separately with a portion of the conbustible elastomeric polymer and thereafter the

separate mixtures are combined to form the propellant. As a still further precaution in a special aspect of my invention my high energy additives containing the hydrides may be mixed, coated or encapsulated with a slow-burning polymer material preferably elastomeric (or with a solution thereof and part or most of the solvent thereafter removed) and then processed as described.

One function of the hydrides is to "trigger" the action to initiate combustion of the more stable components of the high energy additive mixture namely the boron and beryllium and their nitrides. The latter are more stable and do not require as careful handling, although certain precautions are required in all operations relating to rocket propellants generally. The same type of fuel binders namely the combustible elastomeric organic polymers, (which are discussed in detail below), are mixed with the mixture of finely divided high energy fuel additives, and the finely divided oxidizers separately and they are then later combined.

The finely divided high energy fuel additives are generally less than 50 microns in diameter and preferably less than 10 microns in size when incorporated in the solid elastomeric fuel binder.

The oxidizer which is also incorporated in finely divided solid form in the "solid" elastomeric fuel binder may be selected from a group of solid oxidation compounds each of which has its own availability of oxygen for the combustion of the fuel binder and the added high energy finely divided solids. Among the oxidizers may be mentioned ammonium, potassium, lithium and sodium perchlorates (respectively NH_4ClO_4, $KClO_4$, $LiClO_4$ and $NaClO_3$) and other well known and conventional oxidizing agents, e.g., nitrates, performing a similar function. However, because of my superior combination of solid fuel materials I obtain improved results. The selection of an oxidizing agent for example; with the exception of ammonium perchlorate and nitrate all of those named form a dense smoky exhaust because the residues KCl and NaCl (and LiCl) are finely divided solids. Other types like nitronium perchlorate (NO_2ClO_4) does not leave a solid residue (and has the highest (66%) available weight percent of oxygen) but is very powerful and sensitive and therefore difficult to handle. Ammonium perchlorate is generally preferred because as stated it leaves no solid residue and while considerably lower in available oxygen (34%) than the other perchlorates it is much higher than ammonium nitrate with oxygen availability of 20%. All of the perchlorate oxidizers and others are included for possible use in my invention as there is a wide selection in conventional use.

In the final composite the elastomeric material acts as a fuel binder (the external phase) for both the finely divided high energy fuels referred to above and the oxidizers; both of which in effect are in the internal phase.

With regard to the fuel binders, the materials I employ are combustible elastomers, i.e., combustible elastic polymers including the compounded and processed raw polymers having these two prime properties, among which the combustible rubbers and elastomers are the preferred group. The term elastomer has a broader meaning than the term rubber in that the former, while exhibiting elasticity need not return relatively rapidly to approximately its original dimensions when stretched. It is pointed out that while rubbers may be plastic in the raw stage they may also be altered by curing and by vulcanization.

Also, both the raw stock and the cured and/or the compounded and cured elastomeric materials should possess to a substantial degree the properties described; and it is the balance of these properties in the fuel binder which determine their suitability for my invention. In some cases where the values of all of the required properties are present in two or more compatible materials and are not cancelled out they may be blended with each other. In this connection the combustible rubbers (both natural and synthetic) are a preferred class as fuel binders in connection with my invention.

In order to further clarify certain aspects of my invention it is desirable to define and differentiate certain other classes of materials which are considered organic compound polymers and in some superficial respects resemble those I employ, but are generally referred to simply as plastics, the characteristic property of which is plasticity but which are essentially non-elastic from a practical viewpoint. Thermoplastic materials in this class may be repeatedly formed or deformed by pressure and heat whereas thermosetting materials lose this property. Some of these normally plastic materials may be converted into elastomers by compounding and processing.

Some fuel binder materials possess the required elasticity, tensile strength, low brittle point but may exhibit somewhat slow combustion. Providing they are not self-extinguishing the addition of my high energy finely divided additives in such cases may improve considerably the burning properties of such fuel binders which otherwise might not be useful. Also elastomers which show good elasticity and good combustion properties but may lack tensile strength may if compatible be incorporated with them if necessary.

The addition of both the high energy additives and the finely divided solid oxidizer makes it necessary for proper functioning to use an elastomeric fuel binder in any event so that the final mixture in the rocket casing has physical properties which might be compared to use a simple analogy to those of an ordinary pencil eraser to function properly.

With regard to various classifications of rubbers and rubber-like plastics, Fisher (Ind. Eng. Chem., 1939, 31, 941) presents a number of subdivisions under the broad category of elastomers such as (a) elastoprenes derivatives of butadiene and related rubbers; the isoprene rubbers which would include natural rubber and synthetic isoprene rubber, the dimethyl butadiene rubbers and the haloprene rubbers illustrated by neoprene below; (b) elastolenes illustrated by polyisobutylene (which could include the butyl rubber shown in the table classification) and others illustrated by vistanex, etc.; (c) elastothiomers poly-alkalene sulphides including the thiokols, perduran, etc. The above in effect would represent the synthetic rubbers in the Fisher classification. In addition Fisher adds to his classification of elastomers a class with an increasing number of rubber-like plastics either as such or to which plasticizers or other substances have been added which he refers to as (d) elastoplastics which includes rubber-like polymers of acrylic and methacrylic esters; plexigum (a solution of acrylic resins in ethylene dicloride), mixed glyptals, plasticized polyvinyl chloride (e.g., koroseal, etc.) and others, for example polyvinyl acetate, and polystyrene exhibit elastic properties at 40° C. and 65° C., respectively. The Fisher classification also shows plastomers which includes the true thermoplastics and the thermosetting plastics, i.e., those exhibiting little or no elastic properties, as discussed above.

A still more extensive classification of commercial resins and polymers is shown by Winding and Hiatt (Polymeric Materials, McGraw Hill, 1961, pp. 17 and 18, Table 1—1). These are divided into five principal classes which in turn are divided into numerous groups or subclasses of the same. As illustrative (I) Derivatives of Natural Products (A) Natural Resins, (B) Cellulose Derivative, (C) Rubber Derivatives, e.g., chlorinated rubbers. (II) Resins formed by condensation polymerization (A) Phenolic Resins, (B) Amino Resins, (C) Poly-esters, (D) urethanes, (E) Polyamides, (F) Epoxies, (G) Poly-esters. (III) Ethenic polymers, (A) Polyethylene, (B) Polypropylene, (C) Poly-isobutylene, (D) Fluorocarbon polymers, (E) Polyvinyl acetate and its derivatives, (F) Vinyl-chloride polymers and copolymers, (G) Poly-vinylidene chloride, (H) Polystyrene, (I) Acrylic polymers, (J) Coumarene-indene polymers, (K) Poly-vinyl ethers, (L)

Polyvinyl ketones, (M) Polyvinyl amines (N) Divinyl polymers. (IV) Silicones. (V) Rubbers. Group (V) which includes the rubbers will be discussed in detail below in connection with Table 1.

Groups (I) to (IV) (and sub-classes) include the true thermosetting class of plastics (like the phenol, urea and melamine formaldehydes) which in general are non-combustible and otherwise unsuitable for my invention, and the thermoplastic classes (referred to by Fisher as Plastomers) and in addition contains some materials which could be considered as elastomers designated by Fisher as elastoplastics.

Certain materials designated as "slow" rubbery types, which include some of the most widely used synthetic rubbers may show good tensile strentgh and low brittle point in varying degrees, and both classes of elastomers may be suitable as a binder in connection with my invention providing they are combustible.

In testing these elastomeric materials a bending stress test is applied to the breakpoint at various temperatures under standardized conditions and the brittle or freezing point, an important characteristic is determined. Elongation and tensile strength, together with flammability and brittle point generally distinguish the elastomeric fuel binders which are suitable from those of the typically plastic types and the non-inflammable, self-extinguishing elastomers for example those containing halogenes.

The following Table 1 from Winding and Hiatt shows a more complete classification of the principal types of rubbers.

TABLE 1

(I) Polyisoprene
  (A) Cis. (1) Natural (NR) (2) Synthetic rubber (IR)
  (B) Trans. (1) Gutta Percha (2) Balata
(II) Polybutadiene (BR)—of various types
(III) Polychloroprene (CR)
(IV) Butadiene Copolymers
  (A) SBR (GRS) (1) Hot Rubbers (2) Cold Rubbers
  (B) Nitrile Rubber (NBR) with varying amounts of acrylonitrile to vary oil resistance.
(V) Isobutylene—isoprene copolymers (IR) with varying amounts of isoprene
(VI) Polysulphide rubbers
  (A) High mol. wt. linear (B) Moderate mol wt. branched (C) Liquid Polymers
(VII) Chlorinated polyethylene
(VIII) Polyurethane Rubbers
(IX) Silicone Rubbers
(X) Polymers containing fluorine

The classification corresponds to ASTM–D–1418–56T—Tenative for Nomenclature for Synthetic Elastomers. (The observations are indicated in above table.) BR, butadiene rubbers; IR, isoprene rubbers, synthetic; CR, Chloroprene rubbers; NR, isoprene rubber, natural; IIR isobutylene—isoprene rubbers; NBR, nitrile—butadiene rubbers; NCR nitrile—chloroprene rubbers; SBR, styrene—butadiene rubbers.

Except for those rubbers containing halogens (chlorine and fluorine) in substantial amounts (Group VII and X) (Sufficient to interfere with burning, and to be self-extinguishing) and in the case of most silicones (IX) all of the other groups are entirely satisfactory from the viewpoints of flammability (see previous note on neoprene exception), as well as elongation (an index of elasticity in rubber) tensile strength and brittle points, for use in connection with my invention.

One of the special rubbers employed by me as solid fuel binder in connection with my invention is polyurethene rubber. The poly-urethanes appear in the Winding and Hiatt classification (A) as a commercial (synthetic) resin (p. 17) Group (II), subgroup (D), and (B) in the classification of the principal types of rubbers (p. 381). It is only in the latter class that it is used in connection with my invention as a solid urethane (elastic) gum and in the vulcanized or cured polyurethane rubber made therefrom. In general the polyurethane elastomers or rubbers have tensile strength of the order of 4,000 p.s.i., densities of 1.1 to 1.3; elongations of 100 to 700%; good resilience and low brittle temperature of the order of −60° F. to −90° F. and show good workability and are combustible and, while these characteristics may vary widely they serve to distinguish from the non-elastomer type of polyurethanes.

In summary all of the rubbers shown in the Winding & Hiatt classification (p. 381) and Table II above are suitable for my invention as solid propellant fuel binders except those as has been already noted which are not inflammable and are self-extinguishing generally due to the presence of fairly large proportions of halogens. Neoprene is in this general group and is slowly self-extinguishing when ignited. However, it has all of the other desirable properties and when blended with sufficient amounts of inflammable elastomers, especially with the addition of my high energy additive it may be utilized.

It is noted further in connection with my invention that the classification of commercial resins and polymers (Windings & Hiatt, p. 17) referred to above (excluding Group (V) which are in the broader classification of Rubbers) that a considerable number of materials with elastomeric properties are mentioned. These especially include elastomeric polymers which the Fisher classification refers to as Elastolenes and which are in Group (III) in the Winding & Hiatt classification as Ethenic polymers including polyethylene, polypropylene and polyisobutylene which cannot be vulcanized, but have properties similar to unvulcanized rubber with respect to elasticity and combustibility especially, and may therefore be utilized in my invention.

All of these elastomeric materials are hydrocarbon in composition and burn readily and in general are useful as propellant fuel binders in connection with my invention. Two related hydrocarbon rubber-like materials which are more closely related in a sense as true synthetic rubbers to natural rubber are polyisoprene and polybutadiene. Since they contain double bonds they may be vulcanized like natural rubber. These likewise may be utilized in connection with my invention as fuel binders. All of these are useful alone, in combination with each other, or with the other elastomeric materials mentioned above.

Among the polyesters which are elastomeric and burn readily and are useful in connection with my invention referred to in subgroup (C) (Polyesters) of Group (III) of the Winding & Hiatt classification are the polyacrylic esters which are made by the polymerization of the esters of acrylic acid and the alcohols, resulting in the production of viscous fluids to thermoplastic rubber products having elongation of 300% to 600%, tensile strength of 1200 to 2000 and which are fast burning. These properties may be utilized especially in combination with other materials in my fuel binders.

Other materials in the classification have elastomeric properties most of which are what Fisher refers to as elastoplastics. These in general are of secondary value in connection with my invention compared to the rubbers. Those materials in general which possess both substantially elastomeric and combustible properties may, however, have some direct use as well as in blending with other materials, e.g., which may be deficient in the latter property. This class may include the cellulosic elastoplastics such as ethyl cellulose which is compatible with plasticizers and with cellulose nitrate which burns fast and improves the combustibility of ethyl cellulose. It is heat stable and converts to rubber-like materials in working. Cellulose acetate butyrate likewise shows good properties and is compatible with various other materials.

Among the polyvinyl compounds, most of them like polyvinyl chloride, polyvinyl-chloride-acetate, poly-

vinylidene chloride show good tensile strengths and elongation when plasticized but are generally non-combustible or self-extinguishing and therefore cannot be utilized as fuel binders. The same is true as noted above of the halongenated (chlorine and fluorine) natural and synthetic rubbers but these may be used as coating materials for the oxidizers in connection with other aspects of my invention.

The true thermosetting polymers including the phenol formaldehydes, the urea formaldehydes and the melamine formaldehydes are generally non-inflammable and/or self-extinguishing and in addition are low in elongation or elasticity polymerization have similar properties.

As a generalization, it may be stated that polymers which are non-inflammable or are self-extinguishing are not suitable as fuel binders in my invention, but they may be used as coating materials as discussed below.

In addition to making mixtures of various compatible materials to complement and supplement the necessary properties of high elasticity and tensile strength, low brittle point and good combustibility, it is also desirable to select the components of such mixtures on the basis of improving the processing of my novel rocket propellant fuel to the desired end product. For example, mixing all the components, e.g., the fuel binder, the oxidizer and the high energy additive while the fuel binder is in the liquid state and then vulcanizing the fuel binder in order to obtain the desired rocket propellant grain. Also the improvement of the mixture may be necessary to extrude, mold or machine the same, dependent on its characteristics. In addition to selection of single types of fuel binders already described, or of mixtures of the same it may be desirable to make copolymers and interpolymers of the monomers from which the polyers are made; or of reacting the polymers while in an intermediate stage with each other, all directed to facilitating the production of the desired end product.

Compounding and processing of synthetic rubbers and elastomers employed as fuel binders is similar to that of natural rubbers with some variations adapted to the particular materials and end products. The steps so far as the present invention is concerned are compounding, mixing, forming and vulcanization. Processing equipment, generally comprises the usual mixers including the Banbury and sigma blade-type mixers as well as rolling equipment. Forming is accomplished by molding, casting, extrusion and machining.

The shaped mixture is referred to as the grain. It is prepared for installation in the rocket body or case by: (a) casting; (b) compression molding; (c) dry extrusion; (d) machining (turning, drilling, packing, pressing); (e) solvent extrusion and combinations thereof, and others.

In casting which is the preferred method of processing because it utilizes as a fluid the polymers and/or the monomers or components from which the fuel binder is prepared. This permits the mixture to be readily made up as a fluid which may be poured into a mold preferably the rocket body or casing which serves as the combustion chamber of the rocket and the polymer binder is cured under controlled temperature conditions. In this method the grain is bonded to a lining or inner sheath of the metal case or combustion chamber comprising the rocket body. The grain may also as described above be extruded, molded or machined in the required shape and size to fit the rocket engine case. It may also as an alternative be cast into a separate mold adapted to fit the rocket engine casing or combustion chamber and withdrawn as it hardens. In all cases it is usual to form the axial passage by means of a mandrel which is withdrawn as the propellant grain hardens with the opening through its length.

The solid propellant of my invention is thus a mixture of a solid (or semi-solid) fuel binder consisting of one or more of the elastomeric organic polymers described above and containing dispersed therein the finely divided solid high energy fuel additives described above and a finely divided solid oxidizer the latter being in sufficient amounts substantially to oxidize the fuels consisting of the elastomeric fuel binder and the finely divided solid high energy fuel additives. The composite solid propellant thus formed is contained in the case which forms the combustion chamber of the rocket engine.

In addition to the combustion chamber the main elements of the rocket engine are a nozzle and an igniter to ignite the rocket fuel. After the rocket is fully prepared and closed; ignition of the propellant grain by means described below causes the latter (consisting of a composite of the elastomeric organic rubber-like polymer which serves as a fuel binder, the dispersed high energy finely divided solid additives and the oxidizer) to undergo combustion forming the hot gases and combustion products generally which pass at high velocity through the nozzle to propel the rocket vehicle forward under high thrust. This very briefly is the essence of the rocket design and operation which will be more fully described below, particularly in connection with the drawings.

Having described in detail the materials used in my invention in the composition of the propellant grain, I shall proceed to describe the rocket engine generally in which it is employed and of which it is a part, and then proceed to a detailed description of the accompanying drawings.

In solid propellant engines as explained above the propellant is contained as a composite solid in the case or combustion chamber. The solid propellant grain contains all of the material necessary for sustaining combustion, namely one of the elastomeric organic polymers referred to above which functions both as a fuel and as a binder or matrix for the high energy finely divided solid fuels and the finely divided solid oxidizer. The rocket engine hardware contains the combustion chamber, a nozzle for exit of the gases produced by the combustion which produces the forward thrust, an igniter the fuel to initiate combustion within the perforation in the propellant grain and on the surface thereof burning from the inside upon all of its exposed surfaces along the length of the chamber towards the inside walls of the chamber in a direction normal to the burning surface until the propellant fuel is consumed. The unburned propellant thus acts as an insulator for the metal walls of the combustion chamber.

The solid propellant does not need pumps (or pressurizing) of the fuel, required for liquid fuels. The combustion chamber for the solid fuel is larger to accommodate the propellant grain and frequently operates at higher pressure. The solid propellant grain as a rule is more storable and therefore ready for use, mainly because of the use of cyrogenic oxidizers in the liquid fuel rockets.

As noted the chamber contains the propellant grain and confines the exhaust gases or reactions products of combustion and must thus be made of high strength material. It is protected from the intense heat by the insulating effect of the unburned propellant grain but also by the insulating effect of a thin layer of slow-burning fuel between the container walls and the propellant grain and adhering to both. The thin layer is made of the elastomeric polymer used in the propellant grain but without the oxidizer and the high energy fuel. In other cases a thin layer of specially selected adherent very slow burning or a practically non-combustible elastomeric or plastomeric material is used. In all these cases this procedure is known as case bonding. When the propellant grain is not case bonded, i.e., adhering directly to the wall of the combustion chamber, it may be wrapped in a layer of an insulating and non-combustible layer material.

One end of the chamber is detachable to permit loading of the grain and assembly. Safety diaphragms or plugs may be used to control maximum pressure. The chamber has means for holding the grain in place to prevent forcing it into the nozzle during acceleration of the vehicle. Mounting and standing provision for storage may

also be provided. Allowances for differences of thermal expansion between metal and grain and sealing against moisture, to prevent reaction and deterioration of high energy additive oxidizer particles and the like are also provided.

In order to prevent excessive heating effects and erosion by the highly heated high velocity gases in the exhaust nozzle ceramic or graphite inserts are placed therein at the throat of the nozzle.

The igniters used for solid propellant rockets are almost exclusively of the pyrotechnic type. It usually consists of a wire heated by electrical resistance which ignites a primer which in turn ignites the main igniter charge and then the propellant grain. The igniter is sometimes referred to as a squib. The igniter in some cases is positioned in the forward end of the chamber.

The shape particularly with regard to the cross-section of the perforation or opening of the longitudinal axis of the grain is also a determining factor in the rate of burning of the grain and the resulting thrust of the rocket. The shape of the opening may thus be in the form of a star, with varying number of points, cruciform, circular, etc. The use of inhibitors or slow-burning chemicals may if desired be used on the surfaces to slow down burning. The rate of burning (normal to the burning surface) is measured in linear distance per unit of time, and varies with chamber pressure as well as other factors. The pressure may be varied by varying the throat of the nozzle.

With regard to the general operation of rockets, the hot gaseous products of combustion escape with high velocity through the nozzle or throat of the chamber and thereby produces a powerful force equal and opposite to that of the jet which propels the rocket engine, and the frame, and in general the rocket thus overcoming starting inertia and resistance of the air to sustain flight. The force or thrust produced is generally constant which causes the rocket to be accelerated at a progressively higher rate, since the total weight of the vehicle is diminished as the propellants are consumed. The force may be expressed in various units such as pounds of force or rate of doing work such as horsepower, which is a measure of thrust and velocity, but the conventional measure for rockets is generally specific impulse, i.e., the number of pounds of thrust produced per pound of propellant consumed per second. However, there are other features of efficiency of my rocket fuels which will also be referred to below.

The simple rocket as described in practice may be generally balanced for flight but without guidance means. Control of the flight path of a rocket propelled vehicle may be obtained by various methods including fins and in some cases swiveling the engine itself. If the system includes guidance means so that its trajectory or flight path may be altered by a mechanism within the rocket it is generally referred to as a guided missile. The latter generally contains electronic and optical devices, radar, television, etc., for observation. Both may contain a warhead. Generally anything beyond the bare essentials of flight is referred to as payload.

I may apply my invention to all of the above variations and may employ all of the known devices and refinements in connection therewith including multistage systems (including multi-engines) to obtain higher velocities and range. However, in its essence my invention relates more specifically to the improved fuel described herein and to its application to improving the efficiency of the process of rocket engine systems; and more particularly of solid propellant rocket engine systems, including the composite propellant grain and the rocket process connected therewith.

EXAMPLES OF PREPARATION OF THE PROPELLANT GRAIN

The propellant grain may usually be formed by one of several methods. The preferred method is to start with the elastomeric material as a liquid or in the fluid state generally either by raising the temperature of the elastomer or the use of one which is naturally in the liquid state, as such or in an intermediate stage, and adding the finely divided solids to the same. The preferred method of adding the solids is to mix a portion of the elastomer with the finely divided high energy solids; and another portion of the elastomer with the finely divided oxidizer and thereafter combine both mixtures. A special and in some cases preferred method of preparation may be used as a precaution with respect to preventing premature reaction between the highly active finely divided high energy solid and the oxidizer. This method generally refers to coating or encapsulating the finely divided high energy fuel additives, e.g., boron or beryllium and nitrides thereof to which hydrides have been added, with slow burning elastomeric (or plastomeric) material by dissolving the latter in a solvent and mixing with the mixture containing the hydride before adding to the composite.

The entire mass after mixing thoroughly is then poured or formed into the desired shapes. One aspect of this procedure as applied to my invention is to utilize a rubber or elastomer generally in admixture with another of the combustible polymer types described above which may have less elasticity. The elastomer may be of a hydrocarbon type such as natural rubber, polyethylene, polypropylene, polyisobutylene and the like. The use of polybutadiene or polyisoprene in combination with the last named group of hydrocarbons would permit a degree of curing or vulcanization of the mixture. The procedure of incorporating the hydrides, etc., in admixture with a portion of the combustible fuel binder and separately incorporating the finely divided solid oxidizer and combining the two mixtures has already been referred to above, and this procedure is likewise employed in the succeeding examples relating to preparation of the propellant grain. I may also as found desirable or necessary incorporate in the mixture of all of the compounds as described above, a small percentage, e.g., from 0.0% to 5% of a burning rate catalyst to control the rate of burning. Among these iron oxide, copper, chromite and various ferrocyanides, e.g., those of nickel and copper all in finely divided form have been found suitable as well as others.

(A) The method most preferred is to use a relatively low molecular weight liquid polymer, which has chemically reactive groups in the molecule permitting it to be cured or vulcanized to a solid after the finely divided high energy additive and the finely divided oxidizer and the curing agent have been incorporated (as described above) with the liquid polymer and thereafter curing or vulcanizing the liquid polymer to an elastomeric or rubber-like solid. This method generally produces a case bonded propellant grain which is most desirable both from the viewpoints of the grain itself as well as the method of preparation. Normally before the grain is cast the inner surface of the case is prepared by fixing a layer of the elastomer without the dispersed solid, (i.e., the high energy solid or oxidizer); or a non-inflammable layer (like rubber or elastomer containing a halogen) made by dissolving the elastomer in a solvent, applying the same and drying. There are several outstanding examples in this group used in connection with my invention which are discussed below. They have been discussed above and are reviewed in the present context.

(a) Thiokols or polysulphide rubbers

Foremost in this group are the polysulphide types known as the Thiokols or polysulphide rubbers of which there are several types and which have already been referred to above.

In general the Thiokols may be blended with rubbers and sofeners, extruded, calendered, molded and otherwise worked. Also some types require plasticizers. Carbon black and fillers are required to bring out the wearing qualities. The liquid Thiokol polymers are of special interest in the present connection with my invention. They

are solvent free and may even be cured at room temperatures. In some formulations the liquid polymer may be cured to rubbers, e.g., at 50° F. in a period of 30 minutes. The finely divided hydrides admixed with the boron, beryllium and their carbides and nitrides on a selective basis and the mixture separately mixed with the fuel binder and then combined with a separate portion of the binder mixed with the finely divided oxidizer as previously described. A curing agent is added to the fuel binder before mixing. When poured into the rocket case and formed as described above it forms a case bonded solid rocket propellant grain. As indicated above, the case may be previously lined with cured liquid polymer containing no dispersed oxidizer or high energy solids or other relatively non-inflammable elastomer of the type described above.

(b) Polyurethane rubbers

The casting polyurethane rubbers are different from the millable rubbers. They have a relatively short pot life (which as pointed out above, has been lengthened by variations in reactions) and the prepolymer resulting from the above in liquid condition is mixed as described above separately with the finely divided high energy materials, e.g., boron or beryllium or their carbides and nitrides in admixture with the hydrides mentioned (or with finely divided aluminum) and the oxidizer separately mixed and/or coated as described with the fuel binder, etc., and is made into a final single mixture and quickly cast, after mixing, into the rocket case with all forgoing precautions observed resulting in the case bonded propellant grain.

(c) Polybutadiene-acrylonitrile

The combined liquid polybutadiene-acrylonitrile polymer and liquid plasticizer may be separately mixed with the finely divided high energy fuel additives named above in the one hand and with the finely divided oxidizer on the other and is made into a final single mixture and after thoroughly mixing and the additions of the vulcanizer, e.g., a small amount of sulphur with thiuram or zinc oxide accelerator, is cast into the rocket case with necessary precautions as described for the other case bonding example. Polybutadiene acrylonitrile raw polymers may be blended with rubber, polychloroprene, and thiokol (liquid and solid) in all proportions to make various other types of solid propellant grains. The cured nitrile types of rubbers are resistant to various solvents but the uncured or raw gums are freely soluble in aromatic hydrocarbon solvents, ketones such as acetone and the chlorinated solvents and that it may be plasticized by practically the whole range of plasticizers, softeners and the like.

The special method of coating the high energy finely divided solids, e.g., the hydrides in admixture with boron or beryllium, etc., may be readily applied here as well as in the other examples cited herein but in any event as with all the other examples the high energy finely divided solids are separately mixed with the fuel binder and then added to the mixture of finely divided oxidizer and the fuel binder.

(d) Polyacrylic esters

The polymerizing conditions under which these polymers are made control the nature of the final product. The polymers of methyl acrylate are tough, pliable and rubber-like; those of ethyl acrylate are softer, more rubbery and elastic. In general they have good tensile strength, high elongation and ignite readily. The monomers may be readily polymerized by heat. They may be blended with various other monomers like chloroprene (or an intermediate polymer of the same) which likewise polymerizes (in stages) with heat alone and in the resulting polymer will contribute their high inflammability to overcome the sluggish burning properties of the latter and at the same time improve the rubbery properties of the polyacrylic esters. Partially polymerized polyacrylic esters may also be blended with liquid polysulphide.

In all cases the polyacrylic monomers, or the latter partially polymerized or mixtures as described are mixed with the finely divided boron or beryllium or their carbides and nitrides in admixture with the high energy hydride, etc., and with the oxidizer both groups separately mixed with the fuel binder and/or coated and the mixture blended, cast and cured by heat, with the aid, if necessary in the case of blends, of appropriate curing agents and accelerators.

The above examples are by way of illustration only of particular methods of preparing propellant grains in a solid propellant rocket as applied to my invention and other comparable elastomers may be used in the same manner.

(B) In addition to the method of preparation of case bonded propellant grains, another method of forming a solid propellant charge is to use a two-part mixture, one part consisting of a high molecular weight polymeric elastomer and the second part a solvent and/or plasticizer. As an illustration of the principle plastisol grade (with plasticizer) of polyvinyl chloride-acetate may be slurried with a plasticizer, e.g., dibutyl sebacate and when heated become a solid mass.

This principle applied to the present invention may utilize raw or partially vulcanized butadiene-acrylo-nitrile rubber to which is added the plasticizer dibutyl sebacate containing the finely divided oxidizer ammonium chlorate. The finely divided high energy additives of the types already described in admixture may be added partially polymerized chloroprene (with a small amount of curing agent for the nitrile rubber) while still in the fluid state and the slurry mixed. This principle may be applied to other mixtures also.

The hydrides in admixture with the boorn or beryllium or carbides or nitrides of the same may be coated with a polymer in this type of operation dissolved in a compatible solvent, removing the excess of the latter before making the composite mixture containing the solid fuel binder and the oxidizer. The mixture may be formed and solidified on heating.

(C) In still another method of processing solid propellants the finely divided boron or beryllium, etc., may be mixed with the high energy hydride additive and the mixture separately coated with an elastomeric material containing the oxidizer which meets the fuel binder requirements as outlined above and in addition having pressure sensitive adhesive properties which would permit pressing or molding. The elastomer may be dissolved in a solvent, the materials coated and the solvent is then vaporized off at least in part after or during forming. Polyisobutylene is an example of the fuel binder and butyl rubber is another. Both are readily soluble in low boiling aliphatic or aromatic hydrocarbons (e.g., benzene or toluene). Polybutadiene is also in this class with respect to solubility. Masticated rubber and butadiene styrene rubbers are likewise soluble in these solvents. Raw acrylonitrile rubbers are soluble in ketones, aromatic hydrocarbons and chlorinated hydrocarbons. Polyacrylic esters dissolve in benzene and esters.

All of the rubbers and elastomers which have been mentioned as having suitable properties in other respects may be utilized following the above principles or some variation of the same. Moreover, all of these rubbers have suitable working properties when treated with conventional equipment and with conventional fillers, etc. Also, they show a wide range of blending properties with each other.

It is to be understood in any of the cases above I may add conventional materials, plasticizers such as triphenyl phosphate, tricrecyl phosphate, dibutyl sebacate, phthalic acid esters (and numerous others); softeners to enhance tackiness where required, e.g., rosin, rosin oil, coumarin resins, alkyd resins, coal tar, pine tar and substances like lanolin, factices, various waxes and other rubber-blending materials or fillers like carbon black and other found

to impart desirable properties to the elastomer as well as the propellant grain.

In the special method I employ to maximize safety in the handling of the high energy finely divided solid hydrides and especially mixtures of the latter with the high energy finely divided boron, beryllium or their carbides and nitrides are employed in my invention. I may coat or in a broad sense encapsulate the mixture of high energy finely divided solid with a thin coating of substantially non-inflammable organic polymeric elastomer before mixing with the portion of the combustible elastomeric organic fuel binder normally used by dissolving the latter in a solvent (or as a partially polymerized monomer such as chloroprene), and then adding the thus mixed or coated high energy additives to the other components, i.e., a separate mixture of the fuel binder with the oxidizer and proceeding as described for the preparation of the propellant grain above. I may also in some cases apply a thin coating to the high energy additives of substantially non-inflammable elastomers such as polyvinyl chloride (plasticized), polyvinyl chloride acetate (plasticized) dissolved in benzene or various esters; chlorinated rubbers (or those containing halogens in general) soluble in benzene esters or chlorinated solvents; neoprene partially polymerized or dissolved in benzene; soluble silicones; blends of silicones and vinyl polymers dissolved in solvent for both; in Freon or mixtures of the same with gasoline; all may be utilized. Polytrifluorochloro-ethylene which is dissolved at slightly elevated temperatures in ethers, some esters, halogen derivatives and toluene; blends of copolymers of fluoro compounds and polyvinyl chloride may also be used in solution. In connection with this method generally I prefer however the use of a slow-burning organic polymer preferably an elastomer as a coating material and this may be readily prepared by mixing compatible materials in this class with varing degrees of combustibility to obtain the exact type desired.

When the solvent method is employed the excess of the solvent may be removed by evaporation, by gentle heating, leaving the mixture of hydrides and the other components of the high energy fuel referred to above in a form in which it may be mixed with a suitable amount of the fuel binder and then with the remainder of the fuel binder containing the finely divided oxidizer in accordance with the method normally used to complete the formulation of the propellant grain.

In addition to the high energy additives to be mixed with the hydrides, namely boron and beryllium and their nitrides I have disclosed the use of others having similar but non-equivalent functions and properties in the class of high energy additives, namely, finely divided aluminum admixed with the hydrides; and magnesium nitride and/or aluminum nitride admixed with elementary magnesium, and beryllium with magnesium.

These mixtures are in a secondary class in comparison to those containing boron and beryllium, etc., but they are included in my invention and generally speaking they may be employed with the fuel binders and the oxidizers in the same manner as described for the mixtures containing the hydrides and boron and/or beryllium and the propellant grain is completed by adding the finely divided oxidizer in a separate portion of the elastomeric fuel binder. It is therefore to be understood that all of the preceding discussion relating to the preparation of the propellant grain applies to the groups under present discussion. In the case of the aluminum and hydride mixture the latter serves as a high energy fuel as well as a triggering agent, in the case of the nitrides of aluminum and magnesium, together with elementary magnesium the latter is the triggering agent to facilitate combustion of the nitrides.

In general it is to be understood that the specific high energy mixtures which I claim in connection with my invention are unique and are neither equivalent to each other or to any other specific mixtures of the prior art.

SPECIFIC EXAMPLES

The following examples relate to various mixtures within the scope of my invention discussed above:

Since ammonium perchlorate is one of the representative and in balance a preferred oxidizer it is considered in all of the examples, although the others named above may be substituted therefor taking into account the available oxygen in each and their other characteristics.

As a generalization the proportion of oxidizer required may vary from about 60% to about 75% by weight more or less. The size of the oxidizer may vary from about 1 to about 100 to 200 microns more or less and may be blended with a fraction of one percent tricalcium phosphate, talc, etc., to improve flow qualities. Ammonium perchlorate with a specific gravity of 1.9 and has about 34% of available oxgen.

The amount of fuel binder employed varies from about 15% to about 30% more or less including the curing agent. This also includes the binder used in the special method set forth above of coating the surface of the high energy material with a relatively less flammable polymer which also generally has binding qualities.

The amount of finely divided solid high energy fuel additives may vary from about 10 to about 25%. Allowance may also be made in the binder component for minor amounts of plasticizers; (also carbon black and others within the finely divided solid component). The latter in any event is a very small amount except where it is already incorporated in the conventional manner in a rubber binder to improve its properties and which may be selected for use.

Improvements in the solid rocket propellant grain in the examples is based on the increase of specific impulse in pounds of force per pound of fuel per second, designated by Isp., and of course on the latter itself.

In the examples the specific impulse of the elastomer of the rubbers of the type of natural and synthetic and hydrocarbon composition generally and of Thiokol, average about 210 Isp. more or less; that of the polyurethane type rubber averages about 230 Isp. The high energy fuel additives may go as high, e.g., in the case of beryllium and the hydride of beryllium as 340 Isp.; all using ammonium perchlorate as an oxidizer. The increase of the Isp. relates to that of the elastomeric fuel binder when used without the high energy additive. Increased values may also be obtained with varying conditions, e.g., high initial and low final pressures.

Example 1

(a)

	Percent
Fuel binder—Thiokol	20
High energy fuel additive—finely divided beryllium (17%)+LiH (3%)	20
Oxidizer: Ammonium perchlorate	60
	100

Isp., 270%
Increase in Isp. approximately, 30%

(b)

Synthetic rubber of butadiene-styrene, etc., type substituted for Thiokol gives about the same results but the latter may be processed more readily.

(c)

Use of lithium aluminum hydride.

(d)

Of lithium borohydride instead of lithium hydride in 1(a) and 1(b) respectively will give an Isp. of about 275.

Example 2

(a)

	Percent
Fuel binder—Thiokol	20
High energy fuel additive—finely divided beryllium (16%)+BeH_2 (4%)	20
Oxidizer: Ammonium perchlorate (Minor components included)	60
	100

Isp., 280 [1]
Increase in Isp., approx. 30%

[1] Converting the results on a basis of initial and final pressures of 1000 p.s.i. to 2 p.s.i. the Isp. would be about 325.

(b)

Similar results for synthetic rubbers, e.g., of butadiene acrylonitrile type.

(c)

Hydrides of the type named herein, e.g., decaborane may be used with similar results.

Example 3

(a)

	Percent
Fuel binder—Thiokol	18
High energy fuel additive—finely divided boron (15%)+5% decaborane	20
Oxidizer: Ammonium perchlorate (minor components included)	62
	100

Isp., 270
Increase in Isp., approx. 25%

(b)

Similar results for synthetic rubbers, e.g., butadiene-styrene or butadiene acrylonitrile

(c)

Similar results may be obtained with magnesium borohydride and boron.

(d)

Superior results may be obtained with boron and beryllium hydride

Example 4

(a)

	Percent
Fuel Binder—Thiokol	20
High energy fuel additive—finely divided beryllium (15%)+3% BeH_2	18
Oxidizer: Ammonium perchlorate (minor components included)	62
	100

Isp., 275
Increase in Isp., approx. 30%

(b)

Approximately the same for synthetic rubbers of the type noted

Example 5

(a)

	Percent
Fuel binder—Thiokol	20
High energy fuel additive: finely divided boron (15%)+5% decaborane	20
Oxidizer: Ammonium perchlorate (minor components included)	60
	100

Isp., 275 [1]
Increase in Isp., approx. 30%

[1] Converting the results on a basis of initial and final pressure of 1000 to 2 p.s.i. the Isp. would be about 305.

(b)

Approximately the same for synthetic rubbers of the type noted above.

(c)

Various hydrides noted above, e.g., magnesium borohydride gives similar results to (a)

Example 6

(a)

	Percent
Fuel binder—Thiokol	15
High energy fuel additive—finely divided beryllium (20%)+5% BeH_2	25
Oxidizer: Ammonium perchlorate	60
	100

Isp., 290
Increase in Isp., approx. 40%

(b)

Ditto for synthetic rubbers of the type noted.

(c)

Various hydrides noted above all give improved results when used as in (a)

Example 7

(a)

	Percent
Fuel binder—polyurethane rubber	18
High energy fuel additive—finely divided beryllium (16%)+4% BeH_2	20
Oxidizer: Ammonium perchlorate (minor components included)	62
	100

Isp., 285 [1]
Increase in Isp., approx. 25%

[1] Conversion of above to a basis of initial and final pressure of 1000 to 2 p.s.i. shows Isp. of about 342.

(b)

Other hydride noted herein when used with Be give improved operating results, e.g., decaborane

Example 8

(a)

	Percent
Fuel binder—polyurethane rubber	18
High energy fuel additive—finely divided boron (16%)+4% decaborane	20
Oxidizer: Ammonium perchlorate	62
	100

Isp., 280
Increase in Isp., approx. 20%

Example 9

	Percent
Fuel binder—polyurethane rubber	20
High energy fuel additive—finely divided beryllium (15%)+3% BeH_2	18
Oxidizer: Ammonium perchlorate	62
	100

Isp., 277
Increase in Isp., approx. 20%

Example 10

	Percent
Fuel binder—polyurethane rubber	16
High energy fuel additive—finely divided beryllium (20%)+4% BeH_2	24
Oxidizer: Ammonium perchlorate	60
	100

Isp., 298 [1]
Increase in Isp., approx 28%

[1] Conversion of the above to a basis of initial and final pressures of 1000 and 2 p.s.i. shows Isp. of approximately 358.

EXAMPLE 11

(a) When boron nitride is substituted for boron in Examples 5 and 8 shown above, maintaining other materials and conditions shown in these examples, the results will be comparable to those optained in these examples.

(b) A similar substitution of beryllium nitride for beryllium in Examples 4 and 6 employing other factors in these examples will show some less favorable results, i.e., beryllium nitride does not compare as favorably with beryllium as boron nitride does with boron.

(c) In both Examples 11(a) and 11(a) and variations thereof the boron nitride and the beryllium hydride may be mixed with any of the hydrides mentioned herein, or non-equivalently with elementary magnesium to "trigger" the ignition of the nitrides. The hydride mixtures show results somewhat superior in Isp. to those containing magnesium but the latter is somewhat more stable.

(d) Alternatively but not equivalently magnesium nitride and aluminum nitride as well as aluminum diboride may be triggered with elementary magnesium or with the hydrides mentioned by admixture therewith the latter substances providing a higher Isp. than the magnesium but being less stable. In both cases however the Isp. is considerably higher than that shown by the elastomeric fuel binder without the high energy additive.

(e) Elementary beryllium may also be triggered with minor amounts of elementary magnesium.

None of the examples shown above are equivalent in any sense.

EXAMPLE 12

The use of finely divided aluminum instead of beryllium, boron etc., in the mixtures as shown in the above examples together with one or more of the hydrides shown above has advantages in availability and lower costs. The use of the hydrides mentioned herein improve the Isp. of the rocket fuel employing aluminum alone with the fuel binder while the aluminum stabilizes the rocket fuel mixture containing the hydrides and improves its safety factor in handling. The Isp. of the rocket fuel containing all of the components shown in Examples 1 to 10 with aluminum replacing boron or beryllium and nitrides thereof and similar high energy fuels as well as these shown particularly in Example 11 compare favorably in Isp. with the latter and has the advantages referred to above with the former and of course shows a considerable improvement over the use of the fuel binder without the additives.

It is especially to be noted that all of the hydrides mentioned above may be used in various combinations with the boron and beryllium and their nitrides and substances used similarly referred to above and that I may likewise employ any of the elastomeric binders referred to on a selective basis.

The data in the tables and specifications generally show the range of properties of these various materials and that these also may be used to define those suitable for my invention.

The expression organic polymer or polymeric organic material as defined in the claims (in addition to definitions already given herein) refers to the chemical combination of like or unlike organic compounds to form higher molecular weight compounds by polymerization, copolymerization and interpolymerization reactions, as well as (for compounds of similar properties) by condensation reactions. The liquid semi-solid and solid polymer compounds thus formed are of high to very high molecular weights in ascending order, from liquids to solids.

The term rubber has been defined and where it appears unmodified in the claims it refers to an elastomeric material with the properties of rubber as set forth in some detail herein. This includes both the natural and synthetic rubbers hereinbefore referred to. The term Thiokol is a trade name and refers to the group of organic polysulphide materials (both liquids and solids as well as intermediate) and these terms are used interchangeably herein.

With regard to my special improvement wherein the finely divided combustible high energy compound particles (the hydrides) and mixtures of the same with beryllium, boron, etc., in the solid rocket propellant composition are coated or encapsulated with a very slow burning or difficultly combustible or a substantially non-combustible material, it is to be understood that the primary purpose of this procedure is to prevent the possibility of spontaneous reaction in special cases between the oxidizer and the high energy compound. I may also use the expression, "surrounded with a layer," instead of, "coated," or "encapsulated" since from a practical viewpoint the concentration of the coating materials is preferably highest on the surface of the high energy particles, but may blend into the surrounding matrix of the elastomeric fuel binder.

The term minor amount as used in the claims generally means less than that of other comparable components in the mixture, e.g., in comparing the hydride additive to the beryllium, boron and similar components in admixture therewith. The proportions may, of course, vary as all of the additives are high energy fuels and are cooperative in use.

It is obvious that I may use many variables in connection with my invention as well as the applications and uses of the same. The foregoing examples both general and specific are therefore not to be construed as limiting as they are illustrative only of the broad scope of my invention.

I claim:

1. In a high energy solid rocket propellant composition comprising a combustible elastomeric organic fuel binder, a finely divided solid inorganic oxidizer salt, and an additive mixture of finely divided solid combustible high energy substances, the improvement which consists in said additive mixture containing a high energy fuel relatively difficult to ignite and burn selected from the group consisting of boron, beryllium, boron nitride, beryllium nitride, magnesium nitride, aluminum nitride and aluminum diboride, and another more readily igntable and combustible high energy fuel consisting of a solid hydride to facilitate the ignition and combuston of the more difficult components and of the solid propellant composition and to improve its specific impulse.

2. A high energy solid rocket propellant composition of the type described in claim 1 which comprises a combustible elastomeric organic polymer fuel binder, a finely divided solid inorganic oxidizer salt, and a finely divided combustible solid high energy substance consisting of beryllium to which has been added a minor amount of a

finely divided hydride selected from the group consisting of lithium hydride, lithium aluminum hydride, lithium borohydride, beryllium hydride, aluminum hydride, magnesium hydride, magnesium borohydride, and decaborane, the said hydride being added to facilitate the ignition and combustion of the said beryllium.

3. A high energy solid rocket propellant composition of the type described in claim 1 which comprises a combustible elastomeric organic polymer fuel binder, a finely divided solid inorganic oxidizer salts, and a finely divided combustible solid high energy substance consisting of boron to which has been added a minor amount of a finely divided hydride selected from the group consisting of lithium hydride, lithium aluminum hydride, lithium borohydride, beryllium hydride, aluminum hydride, magnesium hydride, magnesium borohydride, and decaborane, the said hydride being added to facilitate the ignition and combustion of the said boron.

4. A high energy solid rocket propellant composition of the type described in claim 1 wherein the solid hydride is selected from the group consisting of lithium hydride, lithium aluminum hydride, lithium borohydride, beryllium hydride, aluminum hydride, magnesium hydride, magnesium borohydride and decaborane.

5. A high energy solid rocket propellant composition of the type described in claim 1, in which the hydride is present in minor proportions in the mixture relative to the total high energy additive present.

6. In a high energy solid rocket propellant composition comprising a combustible elastomeric organic fuel binder, a finely divided solid inorganic oxidizer salt and an additive mixture of finely divided solid combustible high energy substances, the improvement which consists in said additive mixture containing a high energy fuel relatively difficult to ignite and burn consisting of boron nitride, beryllium nitride, magnesium nitride, aluminum nitride and aluminum diboride, and another more readily ignitable and combustible high energy fuel consisting of magnesium to facilitate the ignition and combustion of the more difficult components and the operability of the solid rocket propellant composition.

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