Nov. 28, 1961 J. W. MULLEN II, ET AL 3,010,279

METHOD OF OPERATING PROPULSION DEVICES

Filed April 8, 1957 5 Sheets-Sheet 1

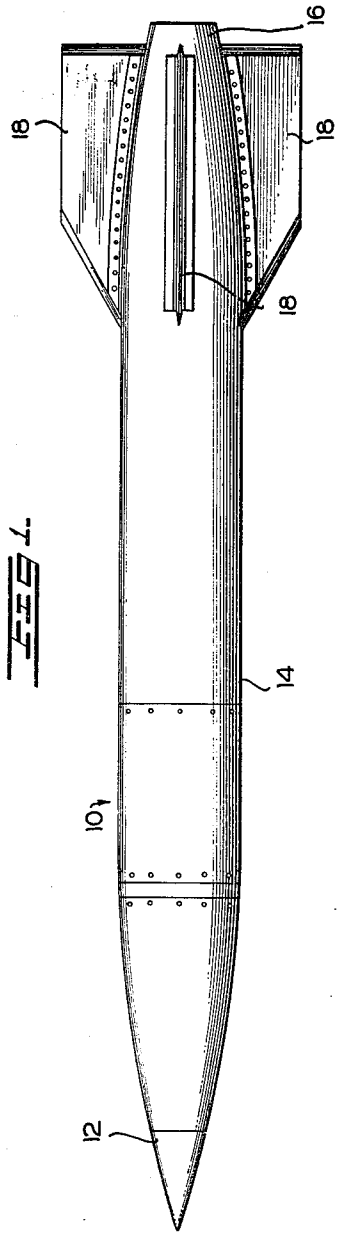


FIG. 1.

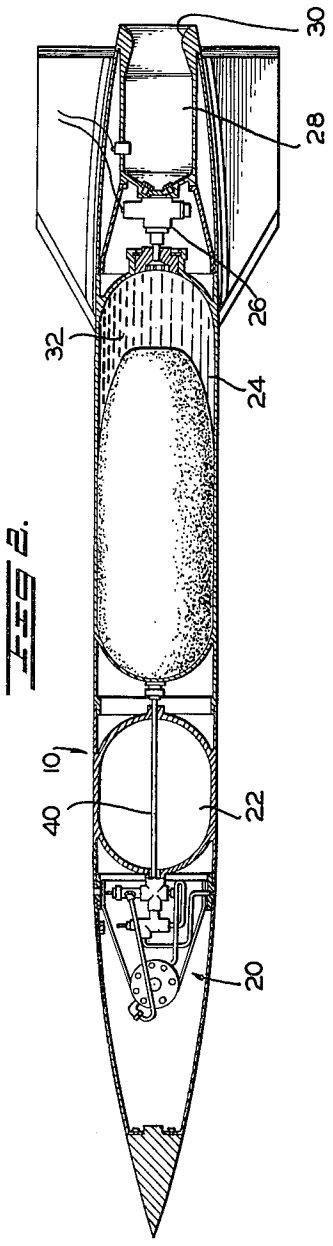


FIG. 2.

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Filed April 8, 1957 5 Sheets-Sheet 2

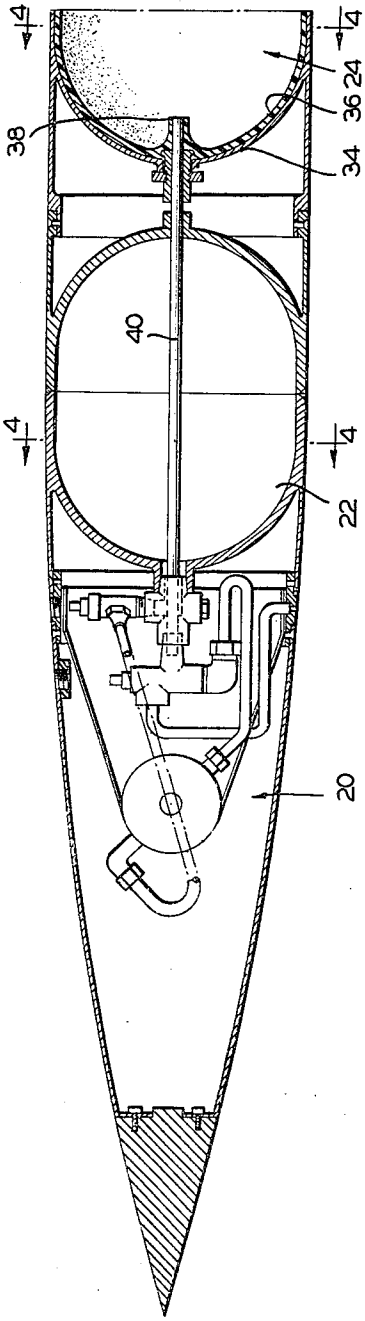


FIG. 3.

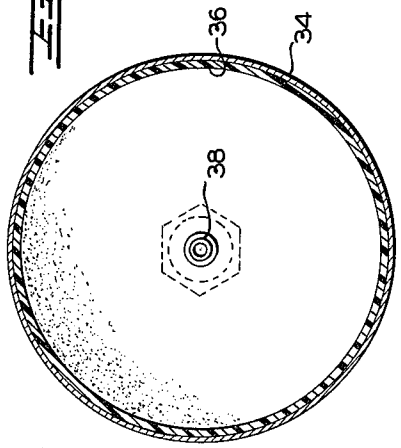


FIG. 5.

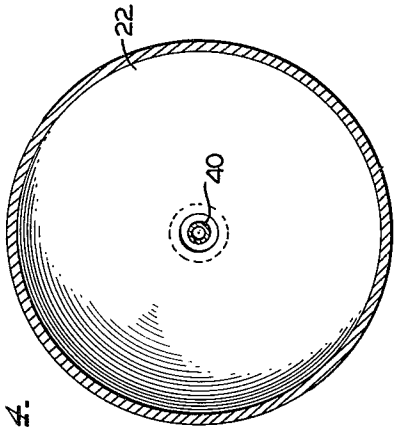


FIG. 4.

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METHOD OF OPERATING PROPULSION DEVICES

Filed April 8, 1957 5 Sheets-Sheet 3

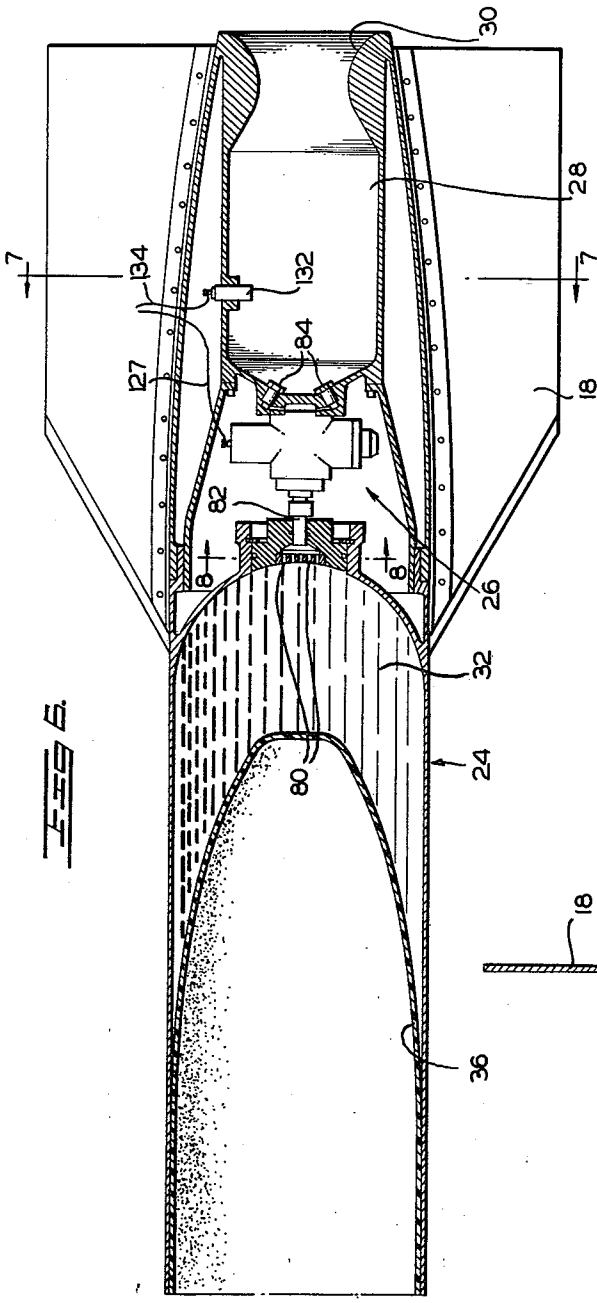


FIG. 6.

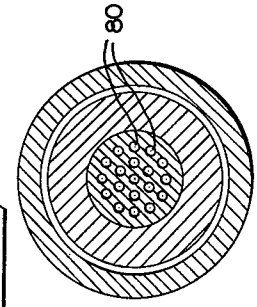


FIG. 8.

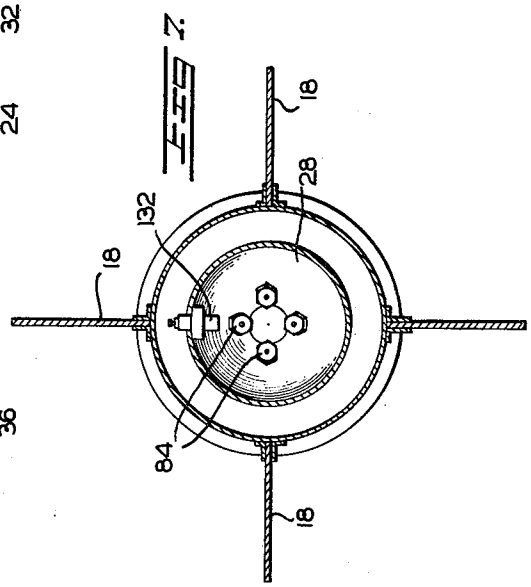


FIG. 7.

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METHOD OF OPERATING PROPULSION DEVICES

Filed April 8, 1957 5 Sheets-Sheet 4

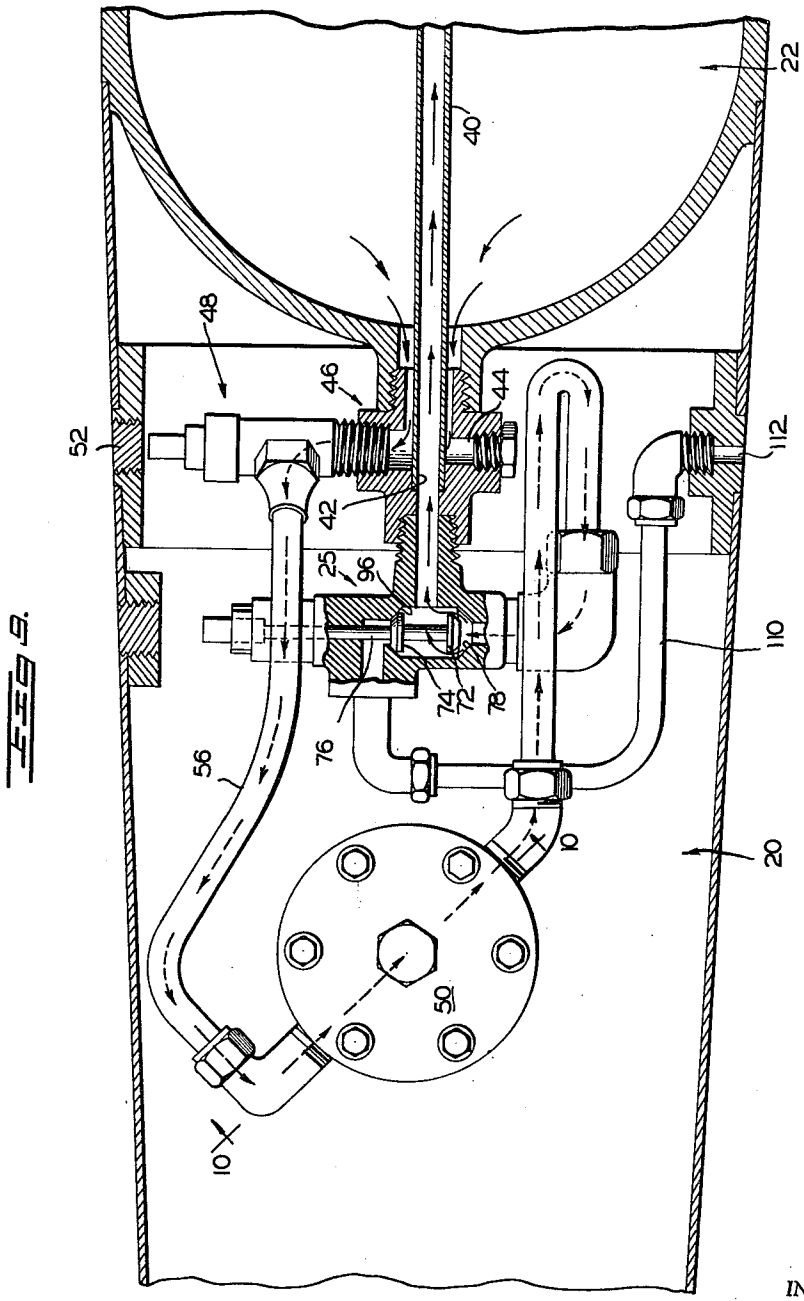


Fig. 9.

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METHOD OF OPERATING PROPULSION DEVICES

Filed April 8, 1957 5 Sheets-Sheet 5

FIG 11.

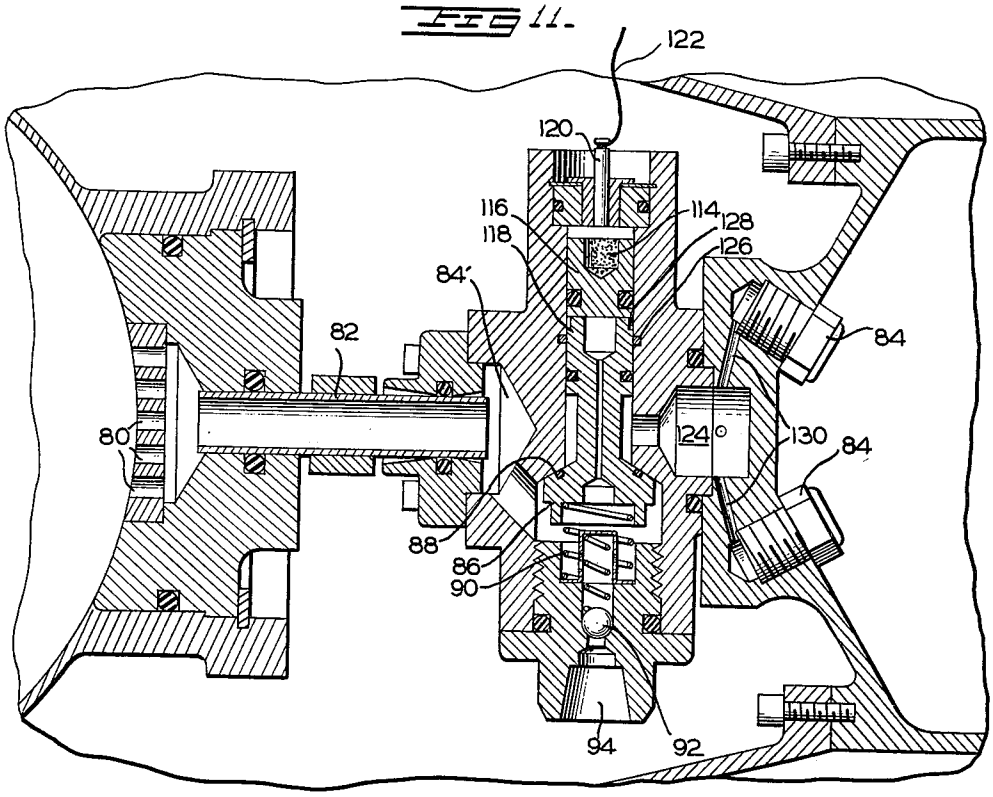
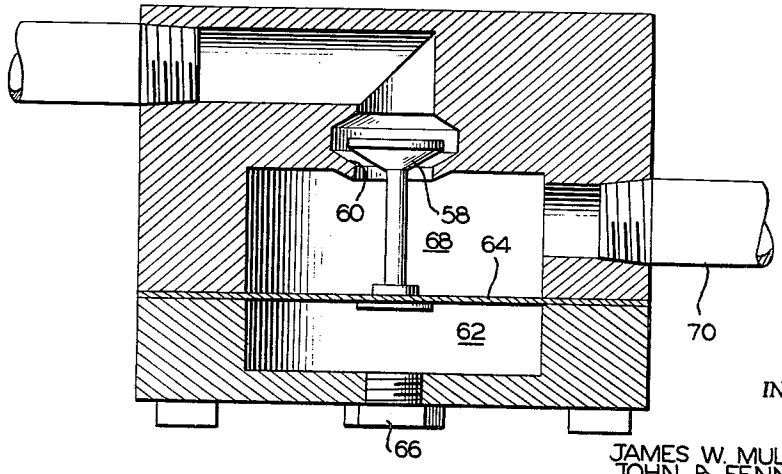


FIG 10.



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3,010,279 METHOD OF OPERATING PROPULSION DEVICES

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Filed Apr. 8, 1957, Ser. No. 651,548
7 Claims. (Cl. 60—35.4)

This invention relates to reaction motors for use as propulsion means for projectiles, missiles, aircraft or other movable devices in which reaction motors are adaptable.

In particular, the invention relates to methods of operation of rocket type reaction propulsion devices wherein the power-producing reaction is brought about by the exothermic decomposition of certain acetylenic fuels which decompose with the formation of solid carbon particles, gaseous decomposition products and the liberation of large quantities of heat.

These and other objects of the present invention will be more clearly apparent to those skilled in the art when considered with the following brief description of the present invention, and the detailed description thereof with reference to the specific embodiments disclosed for the purpose of illustration of the principles of the invention.

Briefly, the present invention is directed to an improved method for promoting the continuous decomposition of compounds and mixtures thereof which decompose with the release of large quantities of heat to form decomposition products which include substantial quantities of solid carbon, and gaseous decomposition products.

In general, the fuels contemplated as within the scope of the present invention are those which decompose with the liberation of heat into an oxidizable decomposition mixture which includes solid carbon particles.

The fuels used in the method of the invention are acetylenic compounds and mixtures of such compounds with each other and with solvents or miscible liquids. Included in the fuels useful in the method of the invention are: acetylenic hydrocarbons, such as acetylene, propyne, including its tautomer, allene, and mixtures thereof with propyne, dimethyl acetylene ethylacetylene and their tautomer 1,3-butadiene, vinylacetylene, a-methylbutene-1-yne-3, 2-methyldivinyl-acetylene, diacetylene, 1,5-hexadiyne, 1,6-heptadiyne, and 1,7-octadiyne; and other acetylenic compounds, particularly the propargyl compounds, such as dipropargyl ether, propargyl alcohol and the mono-, di- and tri-propargylamines, alone or in mixtures. Among the non-acetylenic compounds which may be admixed with the acetylenic compounds are hydrocarbons, such as, kerosene, octane, octene, benzene and other non-acetylenic hydrocarbons containing from about 6 to about 15 carbon atoms, and solvents for the acetylenic compounds, such as acetone and the like.

In general, where compounds which are subject to decomposition with the liberation of heat into combustible decomposition products which include carbon are admixed with non-acetylenic hydrocarbons to form a fuel for use in the method of the present invention from about 0% to about 20% hydrocarbons will provide very satisfactory results. However, such mixtures preferably contain not more than 15% of hydrocarbon.

Of the substantial number of compounds and admixtures which provide satisfactory utility in the method of the present invention it has been found that the following are particularly advantageous:

Propyne, including its tautomer, allene and admixtures thereof with propyne; propargyl compounds particularly dipropargyl ether, propargyl alcohol and propargylamines; and the diacetylenic hydrocarbons particularly 1,5-hexadiyne, 1,6-heptadiyne and 1,7-octadiyne.

The above listed compounds are particularly advantageous because of the large quantities of heat liberated upon decomposition, their relative stability, their availability in large quantities and their adaptability to the method of the present invention. Table I shows some of the chemical and physical properties of some of these preferred fuels.

Table I

Fuel	Molecular Weight	Adiabatic equilibrium decomposition temperature, °F.	Decomposition Products Moles per Mole of fuel			
			C	H_2	CH_4	Other
Propyne	40.06	2,520	2.96	1.92	0.04	------
Propargyl ether	94.1	2,949	4.98	2.95	0.03	1.00
1,6-Heptadiyne	92.13	2,630	6.91	3.82	0.09	------
1,7-Octadiyne	106.16	2,100	7.69	4.38	0.31	------

Throughout the specification and claims the terms "decomposition mixture" means a mixture of the products of decomposition of acetylenic compounds into their elements or into mixtures of elements and simple compounds, or admixtures of said decomposition products with organic compounds.

The effective utilization of the aforementioned fuels by the methods of the present invention which generally comprises directing fuels subject to exothermic decomposition with the formation of solid carbon particles and gaseous decomposition products into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose and removing the products of decomposition at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure in the confined zone, will be more particularly described as applied to the reaction propulsion engine shown in the accompanying drawings in which:

FIG. 1 is a side view of a reaction propulsion engine adapted for carrying out the methods of the invention;

FIG. 2 is a longitudinal, sectional view through the device shown in FIG. 1 with parts of the internal mechanisms shown in section;

FIG. 3 is an enlarged sectional view of the forward portion of the rocket shown in FIG. 1;

FIG. 4 is a section substantially on line 4—4 of FIG. 3;

FIG. 5 is a section substantially on line 5—5 of FIG. 3;

FIG. 6 is an enlarged sectional view of the rearward portion of the device shown in FIG. 1;

FIG. 7 is a section substantially on line 7—7 of FIG. 6;

FIG. 8 is an enlarged fragmentary view substantially on line 8—8 of FIG. 6;

FIG. 9 is an enlarged fragmentary view in partial section of a fuel metering system shown in FIG. 3;

FIG. 10 is an enlarged sectional view substantially on line 10—10 of FIG. 9; and

FIG. 11 is an enlarged fragmentary view of the control valve and nozzle construction for the rocket chamber of the device shown in FIG. 1.

With reference to the drawings there is shown a rocket type reaction propulsion engine embodied in a missile which generally comprises an elongated housing or shell 10 having a streamline nose portion 12, an elongated body portion 14, and a tail portion 16 which tail portion may be provided with stabilizing fins 18 as is well known in the art.

The nose portion 12 of the reaction propulsion vehicle is shown, for convenience, as being small in size and en-

closing only the fuel metering mechanism of the reaction propulsion motor. However, it will be appreciated that rockets constructed in accordance with the principles of this invention would be provided with a nose section suitable for the particular use to which the vehicle is designed.

For example, if the device were to be employed as a missile the nose portion would house suitable high explosives and detonating devices therefor and where desired, control means for guiding the missile to a target. If the rocket is to be used for obtaining meteorological data or the like at high altitudes suitable indicating, recording and/or telemetering equipment would be provided in the nose section.

Within the shell **10** of the rocket, proceeding from the forward end rearwardly, are housed the following structures each of which will be described in detail hereinafter.

Fuel regulator and control mechanism **20**, high pressure gas storage compartment **22**, fuel storage tank **24**, fuel flow initiating valve **26**, rocket chamber **28** and nozzled outlet **30**.

The fuel designated **32** is stored in elongated chamber **24**, the outer wall of which forms the skin of the center section **14** of the missile. In order to transfer the fuel **32** in predetermined quantities to the rocket chamber **28** it is necessary to either pressurize the fuel by means of suitable gas pressure system or pump the fuel into the rocket chamber. Preferably, and as shown in the drawings, a pressurized gas system is employed for transferring the fuel from fuel storage tank **24** to the rocket chamber **28**. The fuel transfer system will be particularly described with reference to FIGS. 3, 4, 5, 6, 8 and 9.

The fuel storage tank **24** is provided about its forward end **34** with a resilient bladder **36**. The resilient bladder **36** separates the fuel **32** from the pressurized gas inlet **38** of conduit **40**, the other end of which communicates with outlet port **42** of valve **25**.

Forwardly of the fuel storage chamber **24** is positioned the pressurized gas storage tank **22** which is charged with a gas such as nitrogen through outlet **44** of T-fitting **46**. A manual shut-off valve **48** is maintained in the closed position during the filling of the gas storage chamber **24** to prevent the passage of gas to the gas flow regulator **50**. In general, suitable operation is provided by preloading the tank **22** with nitrogen at about 2500 pounds per square inch.

When the valve **48** is manually opened, access being had thereto by the removal of plug **52** in the skin of the missile, the compressed gas flows through the valve **48** to the conventional pressure regulator **50** through conduit **56**.

The pressure regulator **50** may be of the type shown in detail in FIG. 10 wherein a valve of the poppet type **58** is moved relative to its seat **60** by predetermined pressure maintained in chamber **62** acting upon diaphragm **64**. An opening closed by plug **66** is provided to preload the pressure chamber **62**. The compressed nitrogen flowing from nitrogen storage chamber **24** through conduit **56** into chamber **68** issues therefrom through conduit **70** at about, for example, 1250 pounds per square inch. Conduit **70** is connected to valve **25**, hereinbefore described, having two valve poppets **72** and **74** controlled by a manually actuated stem **76**.

In operation of the device the valve poppet **72** is moved away from its seat **78** so that the gaseous pressurizing medium may flow from outlet **42** and through conduit **40**, which passes through the nitrogen storage compartment **22**, and into the fuel storage chamber **24** on the bladder side of the fuel **32** whereby the bladder **36** is urged toward the discharge end of the fuel chamber forcing the fuel through the plural outlets **80**, more clearly shown in FIG. 9 and conduit **82** to the flow initiating valve **26**, the discharge port of which connects to the plurality of fuel nozzles **84** positioned at the upstream end of the rocket chamber **28**.

Referring to FIG. 9 the flow initiating valve **26** includes an inlet opening for fuel **84'** and a poppet valve **86** which in the closed position seats about the flange **88** formed in the valve body. Helical spring **90** urges the poppet valve **86** against the seat **88**. At the lower end of the valve body is provided a spring urged ball check **92** which permits communication with an opening **94** for use in filling the fuel chamber **24** with fuel. During the filling of the fuel tank the spring urged ball check **92** moves away from its normal seated position and fuel flows through tthe passage **84**, the conduit **82** and into the tank **24** forcing the bladder **36** towards the forward end of the fuel chamber **24**. Gas or air at the forward end of the bladder **36** is bled therefrom after manual movement of the poppet **74** of valve **25** (FIG. 9) away from its seat **96** so that the gas of air flowing out of the space ahead of the bladder passes through conduit **110** where it exhausts to atmosphere through outlet **112**.

Referring again to flow initiation valve **26**, the poppet valve **86** is moved to the unseated position by a powder charge **114** carried in a pocket in movable piston **116**, slidably connected to the upper end **118** of the poppet valve **86**. An electric igniter **120**, for charge **114**, is connected to an external electrical source through electrode **122**. Upon excitation of the igniter **120**, the powder charge **114** burns, forcing the piston **116** and the poppet valve **86** downwardly so that fuel pressurized, as hereinbefore described, will flow from the inlet of the valve **84** pass the valve seat **88** and into the plenum chamber **124**. A spring type snap ring **126** moves into groove **128** when the poppet valve **86** is moved downwardly by the force of the powder charge **114** so that the valve poppet **86** is held in the open position.

Fuel entering the plenum chamber **124** passes through the plural passages **130** then into the nozzles **84** from which it is sprayed into the rocket chamber **28**.

At the forward end of the rocket chamber **28** is provided a small electrically initiated flare **132** which is connected to an external source of electric power through electrode **134**. The initiation of the electric flare **132** causes the hot products of the burning flare to issue into the rocket chamber **28**. The hot products of combustion from the flare **132** initiate the decomposition of the novel fuels of the present invention. Once decomposition is started, the pressure and temperature within the chamber **28** raise to levels at which the decomposition of freshly injected fuel is self-supporting and proceeds smoothly and continuously. Decomposition products of the fuel issue from rocket chamber **28** through the nozzle **30** positioned at the rearward end of the rocket chamber **28**. To provide continuous decomposition of the fuel a critical pressure and temperature is maintained within the chamber **28** preferably by maintaining at least choking conditions at the exhaust end thereof.

The actual shape of the exhaust opening **30** necessary to maintain at least choking conditions in chamber **28** will depend upon the characteristics of the fuel and rate of decomposition thereof and choking will occur whenever there is a restriction effective to produce a pressure ratio across the restriction of the order of 2 to 1 under the conditions of operation. In the form of the invention shown the nozzle **30** represents such a physical restriction.

When using propyne as the fuel the minimum pressure to sustain the decomposition thereof is about 135 pounds per square inch and the adiabatic equilibrium decomposition temperature is about 2520° F. at 300 p.s.i.a.

The shape and size of the rocket chamber will depend upon the particular fuel employed in the rocket. With propyne, 1 pound of fuel upon decomposition gives 0.9 pound of carbon, 0.1 pound of hydrogen and about 1700 B.t.u.'s of heat.

The high velocity stream of hydrogen containing suspended carbon particles issuing from the nozzle 30 provides the thrust for the vehicle.

Since the hydrogen and carbon from the decomposition of, for example propyne, leave the rocket or decomposition chamber 28, at about 1800° F. static temperature portions of the combustible mixture formed with the surrounding air are in the autoignition region.

Employing propyne as the fuel, the rocket cycle brought about by the decomposition of the fuel in decomposition chamber 42 produces an ideal specific impulse of about 189 seconds at 315 pounds per square inch absolute.

A further example of the operation of reaction propulsion devices by the method the present invention is as follows:

One hundred pounds of liquid propyne $CH_3—C\equiv CH$ is placed in fuel storage tank 24 and the pressurized gas storage tank 22 is filled with nitrogen at 3500 pounds per square inch. The volume of the gas storage tank 22 being about 0.8 cubic foot.

The nozzles 84 are set to deliver a total of about 3.6 pounds of propyne per second into the decomposition chamber having a diameter of 12 inches, a length of 8 inches and an outlet diameter of 2.86 inches at exit and 1.43 at smallest area.

The flow initiation valve 26 and the flare 123 are electrically actuated.

The burning flare causes the pressure and temperature in the rocket chamber to build up and initial flow of propyne into the chamber to decompose into carbon, and hydrogen with the liberation of about 1,700 B.t.u.'s per pound of fuel.

Choking conditions maintained within the chamber 28 by the outlet nozzle 30 causes the remainder of the fuel injected into the chamber to continuously decompose and the process continues automatically until the liquid propyne in tank 24 is exhausted (about 27 seconds), producing about 600 pounds of thrust.

From the foregoing description of the invention and the means for carrying out the invention it will be seen that revolutionary new processes for the operation of reaction propulsion engines have been provided satisfying the aims, objects and advantages of the invention.

This application is a continuation-in-part of application Serial No. 239,952, filed August 2, 1951, now abandoned.

We claim:

1. A method of operating a reaction propulsion engine which comprises directing acetylenic fuels selected from the group consisting of acetylenic hydrocarbons and tautomers thereof, dipropargyl ether, propargyl alcohol and mono-, di- and tri-propargylamine subject to exothermic thermal decomposition with the formation of solid carbon particles and gaseous decomposition products into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

2. A method of operating a reaction propulsion engine which comprises directing fuels consisting of a mixture of acetylenic compounds selected from the group consisting of acetylenic hydrocarbons and tautomers thereof, dipropargyl ether, propargyl alcohol and mono-, di- and tri-propargylamine and organic compounds selected from the group consisting of non-acetylenic hydrocarbons containing from about 6 to about 15 carbon atoms and acetone subject to exothermic thermal decomposition with the formation of solid carbon particles and gaseous decomposition products, said mixture containing at least 80% of acetylenic compounds, into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

3. A method of operating a reaction propulsion engine which comprises directing fuels comprising at least 80% of acetylenic compounds selected from the group consisting of acetylenic hydrocarbons and tautomers thereof, dipropargyl ether, propargyl alcohol and mono-, di- and tri-propargylamine subject to exothermic thermal decomposition with the formation of solid carbon particles and gaseous decomposition products into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

4. A method of operating a reaction propulsion engine which comprises directing acetylenic hydrocarbons subject to exothermic thermal decomposition with the formation of solid carbon particles and gaseous decomposition products into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

5. A method of operating a reaction propulsion engine which comprises directing propyne into a confined zone maintained at conditions of temperature and pressure effective to cause the propyne to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

6. A method of operating a reaction propulsion engine which comprises directing dipropargyl ether subject to exothermic thermal decomposition with the formation of solid carbon particles and gaseous decomposition products into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

7. A method of operating a reaction propulsion engine which comprises directing diacetylenic hydrocarbons subject to exothermic thermal decomposition with the formation of solid carbon particles and gaseous decomposition products into a confined zone maintained at conditions of temperature and pressure effective to cause the fuels to decompose exothermically and permitting the products of decomposition to flow at least at sonic speed from the confined zone while continuing to maintain said conditions of temperature and pressure therein.

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