

April 27, 1965

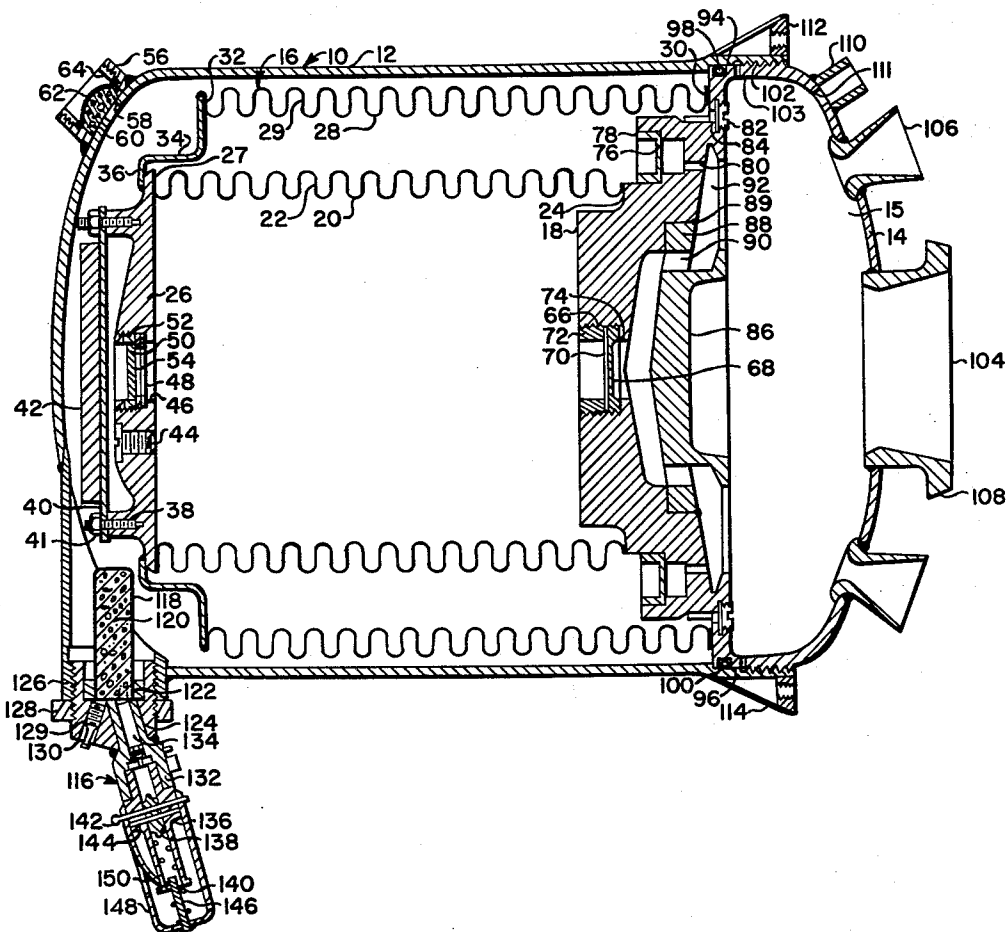
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3,180,089

POSITIVE DISPLACEMENT FUEL FEEDING SYSTEM

Filed Feb. 15, 1960

3 Sheets-Sheet 1



**FIG 1**

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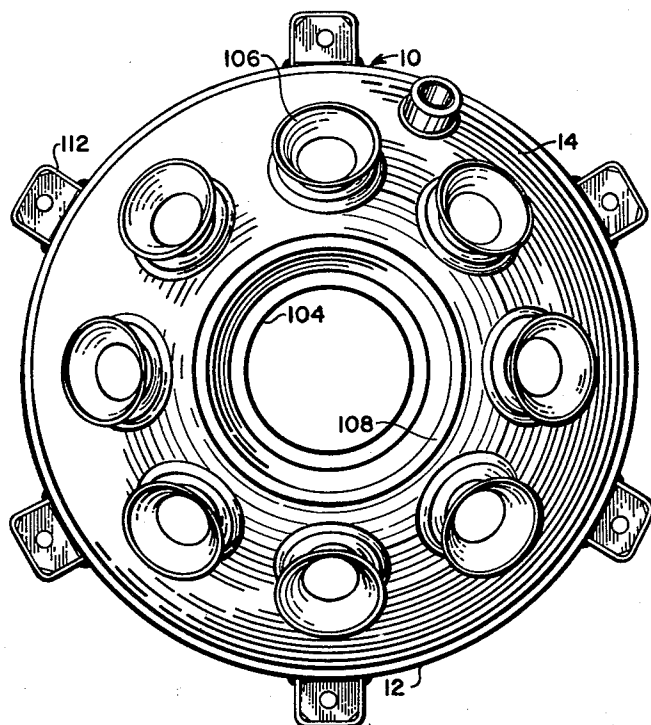
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**FIG 2**

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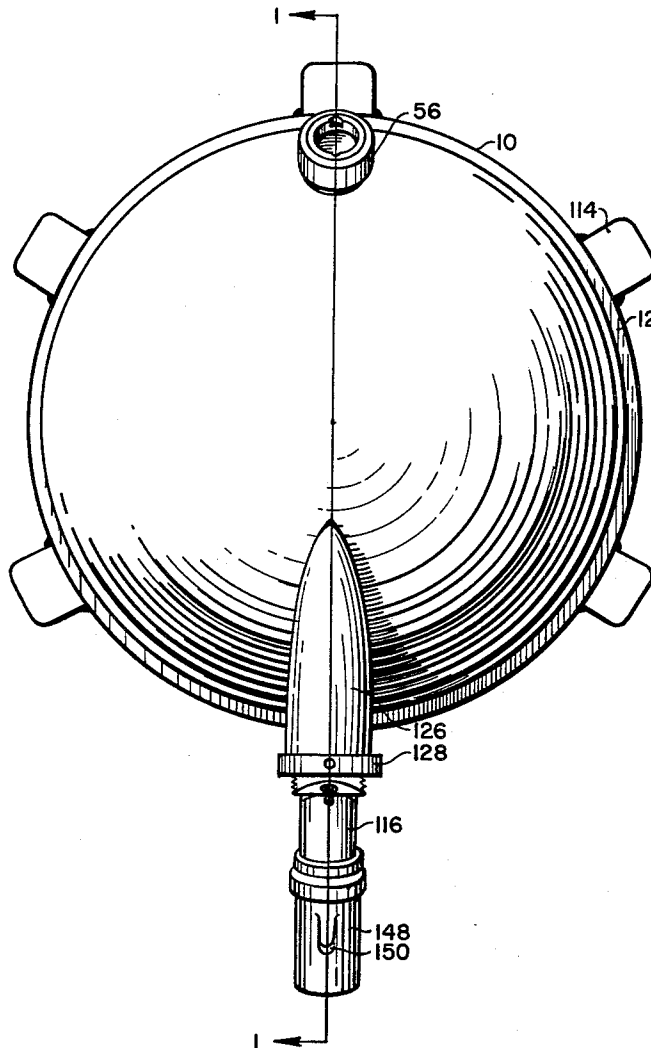
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3 Sheets-Sheet 3



**Fig 3**

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## POSITIVE DISPLACEMENT FUEL FEEDING SYSTEM

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3 Claims. (Cl. 60—39.48)

This invention relates to a device for dispensing fluids and more particularly to means for dispensing fluids under pressure.

This invention is to be used in conjunction with a liquid propellant thrust chamber which operates on a bi-propellant system. When used with a pressurizing gas chamber the device is intended to provide a means of positive displacement of a liquid fuel and an oxidizer into a thrust chamber at such rates that a constant weight-mixture ratio will be maintained between the oxidizer and fuel throughout the operating cycle when propellants are at ambient temperature. The main purpose of this invention is to provide a means of controlling mixture ratio during the starting transient period with particular emphasis upon applications in which a high rate of pressure development is required. The unit is intended to overcome the difficulties normally encountered by a liquid thrust chamber and propellant feed system which may operate at a mixture ratio either higher or lower than the design-mixture ratio during the transient starting period. The device also assures positive displacement of the liquids into the thrust chamber regardless of their physical location with respect to the thrust chamber. No relative motion between the moving parts exists as in normal piston fuel pumps.

Briefly, the invention comprises a rocket housing having a plurality of compressible fuel containers holding fluids wherein said containers are collapsed by gases generated by a propellant to emit the fluid from said containers through a plurality of frangible diaphragms into a combustion chamber where it is ignited and the hot gases of the combustion are directed to the atmosphere through a plurality of nozzles.

An important object of this invention is to provide a positive displacement device capable of dispensing a plurality of fluids at very accurate ratios of the fluid mixture.

A further object is to dispense fluids at extremely short time intervals with high pressure developed under near explosive forces.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein;

FIGURE 1 is a side elevation of the invention having a partial longitudinal cross section taken along line 1—1 in FIGURE 3;

FIGURE 2 is a rear elevation of the invention;

FIGURE 3 is a front elevation of the invention.

Referring now to all the figures, a liquid propellant rocket 10 has a cup-shaped casing 12 and a threadedly received cap 14 which encloses the tank assembly 16 therein. A composite-formed injector plate 18 is received in sealing engagement within the casing 12 and has fixedly attached thereto the bellows 20, being composed of a series of corrugations 22, to the step 24 by a convenient mechanical method such as welding. The combustion chamber 15 is defined between the injector plate 18 and the cap 14. The end closure 26 seals the opposite end of bellows 20 at the extremity 27. A similarly shaped bellows 28 composed of corrugations 29 is fixedly attached to the land 30 of the injector plate 18 by welding at one

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end and to the flange 32 at the opposite end. The Z-shaped skirt 34 having the inwardly and outwardly extending flanges 36 and 32 respectively being attached to the end closure 26 forms the tank assembly into an integral unit.

The unusual starting requirement of the rocket 10 in which full thrust must be obtained within 0.12 second of time of actuation of the fire switch, demands a liquid-propellant system of hypergolic fluids with minimum ignition lag characteristics. The propellant combination of inhibited red fuming nitric acid and unsymmetrical dimethylhydrazine has been successfully used in this requirement.

A plurality of rearwardly extending posts 38 on the end closure 26 support the grain mounting plate 40 that is attached thereto by the bolts 41. A solid propellant grain 42 is attached by appropriate means to the plate 40, which when ignited creates pressurization gases used to collapse the tank assembly 16. An appropriate propellant is disclosed in the application, Serial No. 109,409 assigned to the Aerojet-General Corporation now under a notice of allowability. Other solid and liquid propellants may be used having various combustion rates and forces which are picked in relation to the required total elapsed time for full thrust.

Pressurizing gases, from the solid propellant grain 42 introduced into the space between the tank assembly 16 and the outer case 12, provide the means by which the propellants are compressed out of the tank assembly 16 into the combustion chamber 15. In the process the corrugations 22 and 29 of the bellows 20 and 28 are compressed solidly upon each other. The double case construction permits operation with bellows having an aluminum wall thickness of .015 inch. Since the bellows are integrally connected, mixture ratio control throughout the entire operating system is assured. The wall thickness of the bellows 20 must be sufficient to withstand the pressure differential caused by the different hydraulic characteristics of the fluids contained within each bellows. The bellows tanks are made of relatively pure aluminum, primarily to permit long-term storage of the oxidizer and fuel.

The plug 44 threadedly received by the end closure 26 can be used to fill, vent, or pressure test the inner fluid tank prior to welding the bellows 20 to the injector plate 18 at the step 24. A blow-down diaphragm 48 which is made of a soft frangible aluminum is received by the centrally located bore 46. All diaphragms are protected by a thin membrane seal made of unplasticized Kel-F (Fluorothene-A), a material resistant to both dimethylhydrazine and inhibited red fuming nitric acid. A locking cap 52 retains both the diaphragm 48 and the protective seal 50. A layer of zinc chromate paste 54 is used to insulate the blow-down diaphragm 48 from the hot pressurization gases.

A safety release housing 56 is fixedly attached to the casing 12 above the safety release orifice 58. The size of this orifice will depend upon the criteria established with relation to the amount of gases to be exhausted through the port during periods of malfunction. A layer of zinc chromate paste 60 covers the safety release scored aluminum diaphragm 62 and is retained as an integral subassembly by the threaded retainer 64 within the interior of the housing 56.

Soft aluminum burst diaphragms, of conventional design, are used to control the flow of liquid propellants to the combustion chamber and for blowing down the pressurizing system at the end of the operation. Two diaphragms control the flow of the fluid fuel from the bellows 28 to the injector manifold while one central diaphragm controls the oxidizer flow from the bellows 20. The propellant control diaphragms are designed to rup-

ture under a differential pressure of 175 p.s.i., while the blow-down diaphragms are designed to rupture under a differential pressure of approximately 400 p.s.i. A centrally located bore 66 within the injector plate 18 receives a propellant control diaphragm 68 that is covered by a Fluorothene-A protective seal 70. A threaded retainer 72 forms the diaphragm and seal into an integral assembly and in juxtaposition to the orifice 74 that leads into the combustion chamber.

A cup-shaped propellant control diaphragm 76 is retained by a butyl rubber cement within the bore 78 of the injector plate 18 and vents the outer tank to the combustion chamber 15 through the injector orifice 80. A port 84, plugged by vent cap 82, communicates between the combustion chamber 15 and the external tank or bellows 28 for filling or pressure checking purposes.

A fuel splash ring 86 nests within the bore 88 and is welded to the injector plate 18 at 89. The injector orifice 90 formed within splash ring 86 communicates between the bellows 20 and the combustion chamber 15. The injector orifices 80 and 90 project the hypergolic oxidizer and fuel to the annular shaped cavity 92.

The injector plate periphery 94 is received by the bore 96 at the upper end of the casing 12 and has the O ring seal 98 received by the slot 100 forming a sealing engagement between the injector plate 18 and the casing 12. The cap 14 is threadedly received at the enlargement 102 of the casing 12. A seal 103 is in abutting relation between the injector plate 18 and the cap 14 to create a seal between the combustion chamber and the atmosphere external to the casing 12.

A central nozzle 104 is positioned centrally within the cap 14 and is fixedly attached thereto as by a convenient means such as welding. A plurality of peripheral nozzles are fixedly attached to the cap 14 and canted at approximately 20°. The ring section 108 on the forward portion of the central nozzle 104 for attaching the rocket unit 10 to the superstructure of any desired object to be motivated by the unit. The central nozzle 104 is designed to transmit the maximum expected hold-down loads resulting from negative accelerations upon the object being motivated.

A cylindrical pressure tap 110 is fixedly attached to the cap 14 and positioned over an orifice 111 which is used to duct the gases from the combustion chamber 15 for actuation of ancillary mechanisms.

Six thrust mountings 112 are fixedly attached to the periphery of the casing 12 and act to attach the rocket unit to a thrust plate (not shown). A thrust bracket, bracket 114, forms a strut between the mounting 112 to the outer casing 12.

Positioned at one side of the closed end of the casing 12 is the igniter assembly 116 that is used to detonate the solid propellant 42 and pressurize the interior of casing 12. A charge retainer cage 118 containing an explosive charge 120 (solid propellant plus black powder) is retained by a retainer ring 122. Nut 124 retains the entire igniter assembly 116 and is threadedly received by the snout 126. Locking ring 128 threadedly received by the retainer nut 124 holds the entire unit against the snout 126. A commercial glow plug 130, made by the McCormack-Selph Company, is placed in a passageway 129 that leads to the charge 120. The common glow plug acts as an ignition element having electrically heated resistance wires generally placed in proximity of combustible materials. A detonator body 132 is fixed attached to the passage that also leads to the charge 120 and has contained therein a .25 caliber shell and percussion cap assembly 134 that is kept in position by the striker body 136 which acts to detonate the shell cap 134 which in turn ignites the charge 120. Spring 140 guided within the striker body 136 acts to apply a constant pressure upon the striker 138 causing it to be impacted on the shell and cap 134. Safety and arm lock 142 and the shear pin 144 keep the striker 138 from impaling the shell and cap

134 until the lock 142 is withdrawn. A guide column 146 aligns the spring 140 and tends to keep the entire igniter assembly 116 operating in a straight line. The cup-shaped actuating mechanism 148 is slidingly received by the striker body 136 and is the operating arm or means through which motivating force is directed to shear the pin 144 and drive the striker into the shell and cap 134. A flat spring 150 integral with the actuating mechanism 148 tends to hold the actuating arm 148 from being forced downwardly until the lock 142 is withdrawn thus allowing the igniter assembly to be activated. Following is an operational discussion through which the operator must be directed in order to ignite the rocket.

For example, the fuel and oxidizer tanks, respectively, may be filled with appropriate hypergolic fluid such as unsymmetrical dimethylhydrazine and inhibited red fuming nitric acid at an appropriate ratio which in this case is approximately 2:1. The ports 44 and 82 are used for this purpose to allow admission of the fluids with an ullage of approximately 10% to allow for expansion and contraction during a possible temperature differential between minus 65° to positive 160° F. The fluids may be introduced under pressure of 300 p.s.i.

The unit is inserted into the device which is to be motivated by engaging the attachment ring 108 of the central nozzle 104 to a conventional detachment arrangement. A typical application of the rocket unit is in an aircraft cockpit ejection system. The safety arming pin 142 is left intact and a mechanical arrangement is positioned above the triggering mechanism to allow an operator to ignite the detonator propellant and eject the fuel and oxidizer fluids. The striker 138 of the igniter will engage the firing mechanism which is attached to available structure at the rear of the pilot's seat. A suggested firing mechanism could consist of a cam operated mechanism with two handles and two arming levers. These levers or operating handles should be long enough so that the pilot's motion will be eventually linear rather than rotational. Arming of the circuit is accomplished by the simple motion of compressing either of the two arming levers against the handle. This motion will pull the safety or arming pin 142 from the mechanical igniter and at the same time actuates in the arm position by means of a hold-down clamp. Firing of both the mechanical and electrical igniters is accomplished by pulling either handle in an upward direction. This motion will rotate the cam shaft and force the plunger toward the rocket unit. When the plunger has travelled a linear distance of approximately ¾ inch, a firing micro-switch can be positioned there (not shown) which will close and thereby energize the electrical glow plug 130. At the same time, the striker 138 will be freed in the mechanical circuits and ignite the black powder in the .25 caliber shell. Thus, positive ignition of the rocket unit will have been accomplished even though a failure in the power supply of the aircraft may exist. An alternate method of actuating the detonators is by having a mechanical apparatus collapse the triggering mechanism 148 while an alternate electrical circuit may be available for the pilot to ignite the glow plug 130 in the possibility of a malfunction.

Once the charge 120 is ignited, black powder and solid propellants contained therein will explode causing an increase in temperature and pressure to exist within the casing 12 with the resultant solid propellant 42 igniting to create the pressurization gases necessary to purge the system of the fuel and oxidizer fluids. Although the gases generated by the igniter material do not impinge directly upon the solid propellant 42, it is believed that the initial pressure build-up by the igniter material (approximately 300 p.s.i.) will insure prompt ignition of the propellant.

In the specific example herein illustrated, the propellant grain 42 is cylindrical in shape, having a diameter of 4.25" and a web thickness of 0.40". An average operating pressure between (minus 65° to 160° F.) within the

casing 12 is 1,000 pounds per square inch absolute. The resultant combustion gases emitted from the plurality of nozzles at a high velocity create 9,000 pounds of thrust for 0.24 second. Upon a pressure differential of 175 p.s.i. between the respective fuel and oxidizer tanks and the chamber within the casing 12 the fluids within the tanks are purged by first bursting the propellant control diaphragms which lead to the injector plate and manifold mixing chamber. The fluids being hypergolic, ignition is immediate with the resultant force being formed in the combustion chamber 15 within the cap 14. The entire bellows 20 and 28 are forced to be closed solid until each corrugation 22 is touching each adjacent fold whereupon the blow-down diaphragm 48 will rupture causing the excessive pressurization gas to be vented through the nozzles 104 and 105.

The safety release diaphragm 62 is provided to protect the outer case 12 in the event of a pressurization grain malfunction. This diaphragm 62 protects the casing 12 from rupturing due to an increase in pressurization gases beyond the bursting strength of the case. A controlling orifice 58, approximately 0.22" in diameter is drilled through the outer casing 12. This size of orifice has been found to be effective, however, the size is dependent upon the criteria established with relation to the amount of gases to be exhausted through the port during malfunction.

The width of the outer annulus tank depends upon the operating mixture ratio and upon the density of the particular propellant to be used in the outer tank. It is desirable that this width should be maximum to provide space for the burst diaphragm 76 installation. The size of the burst diaphragms 76 depends upon the particular propellant to be used in the outer tank.

A glow plug 130 is a part of the electrical systems which fires the igniter. This plug is proposed because of its extremely short ignition lag characteristics.

The mechanical igniter makes use of a .25 caliber cartridge and percussion cap assembly 134 to fire a black powder charge 120. A steel striker 138, held by a shear pin 144, gains its energy of motion from a plunger 148 and spring 140 system. Movement of the plunger 148 against the spring 140 and striker 138 assembly will create sufficient force to shear the retaining pin 144 and fire the striker 138 against the percussion cap 134. A safety or arming pin 142 projecting through the striker 138 and the plunger 148 must be removed manually before it is possible to fire the system. The movement of the plunger 148 as it is compressed against the spring 140 engages a microswitch (not shown) which closes and fires the electrical circuit simultaneously with the firing of the mechanical system. Thus, one motion can be used to fire both igniter systems.

While only a single structural arrangement of parts has been illustrated and specifically described herein, and only a few illustrative examples of preferred materials have been given, it is obvious that many other variations and modifications are possible in both the structure and choice of materials, in the light of the teachings of this disclosure. It is accordingly to be understood that the scope of the invention is not intended to be limited by the specific illustrative examples given but rather by the scope and language of the appended claims.

I claim:

1. A positive displacement fuel system having a plurality of axially extending bellows received one within the other, an end plate fixedly attached to said plurality of bellows at one end thereof, a housing receiving said plurality of bellows and said end plate, a cover plate within

said housing in sealing engagement therewith and fixedly attached to said plurality of bellows at the other end thereof, a propellant received by said housing and positioned externally of said plurality of bellows adjacent to said end plate, a plurality of frangible discs disposed in said cover plate communicating between each of said plurality of said bellows and externally of said housing, and a detonating device in communication with said housing capable of igniting said propellant to generate fluid pressure therefrom for urging said end plate axially in a direction compressing said plurality of bellows to purge their contents through said frangible discs.

2. A rocket motor comprising: a housing, an injector plate sealingly received by said housing, a plurality of axially extending fluid containing bellows received within each other and disposed in said housing, said injector plate being fixedly attached to said plurality of bellows at one end thereof, said injector plate having a series of passageways respectively leading from each of said plurality of bellows and terminating in an annular cavity, frangible diaphragms received by said injector plate passageways, a dome-shaped end cap secured to said housing in juxtaposed relation to said injector plate and forming therewith a combustion chamber between said cap and said injector plate communicating with said annular cavity, a series of nozzles fixedly attached and radiating outwardly from said dome-shaped end cap, an end closure within said housing and fixedly attached to said plurality of bellows at the other end thereof, a solid propellant positioned externally of said plurality of bellows adjacent to said end closure and within said housing, and an electrical detonator and a mechanical detonator fixedly attached to said housing capable of igniting said solid propellant and having an initiating means disposed externally of said housing, said solid propellant generating fluid pressure in response to the ignition thereof for urging said end closure axially in a direction compressing said plurality of bellows to rupture said frangible diaphragms for emitting the fluid contained in said plurality of bellows through said injector plate passageways and the annular cavity to the combustion chamber.

3. A rocket motor as set forth in claim 2 in which the electrical detonator comprises glow plug means capable of effecting ignition of said solid propellant upon energization thereof and the said mechanical detonator includes a cartridge and a percussion cap with a metallic striker mechanism operatively associated therewith.

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