

May 21, 1963

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3,090,325

CONTINUOUS FLOW DISPLACEMENT PUMP

Filed Oct. 20, 1958

2 Sheets-Sheet 1

Fig. 1

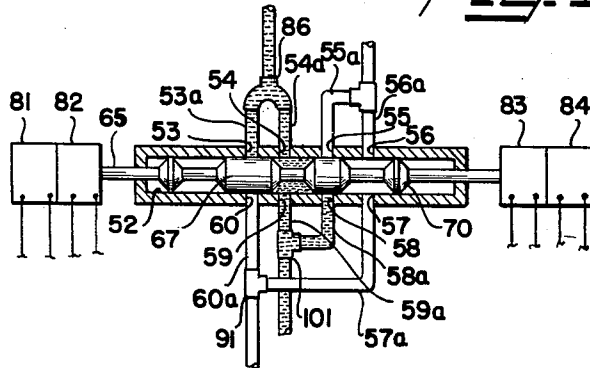


Fig. 3

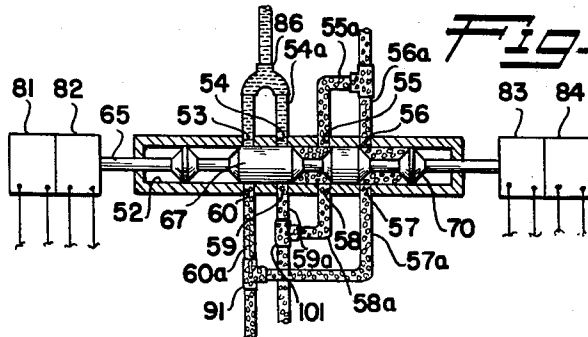


Fig. 4

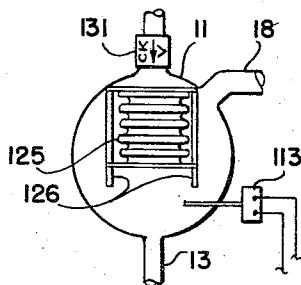
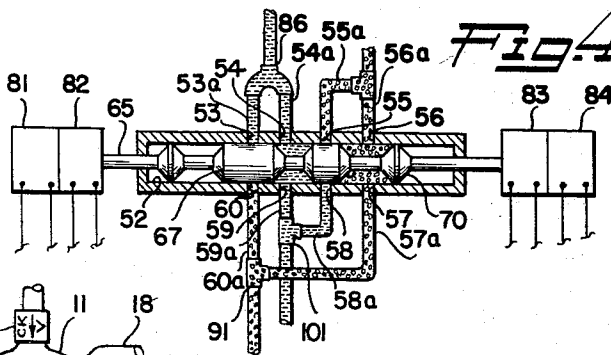


Fig. 5

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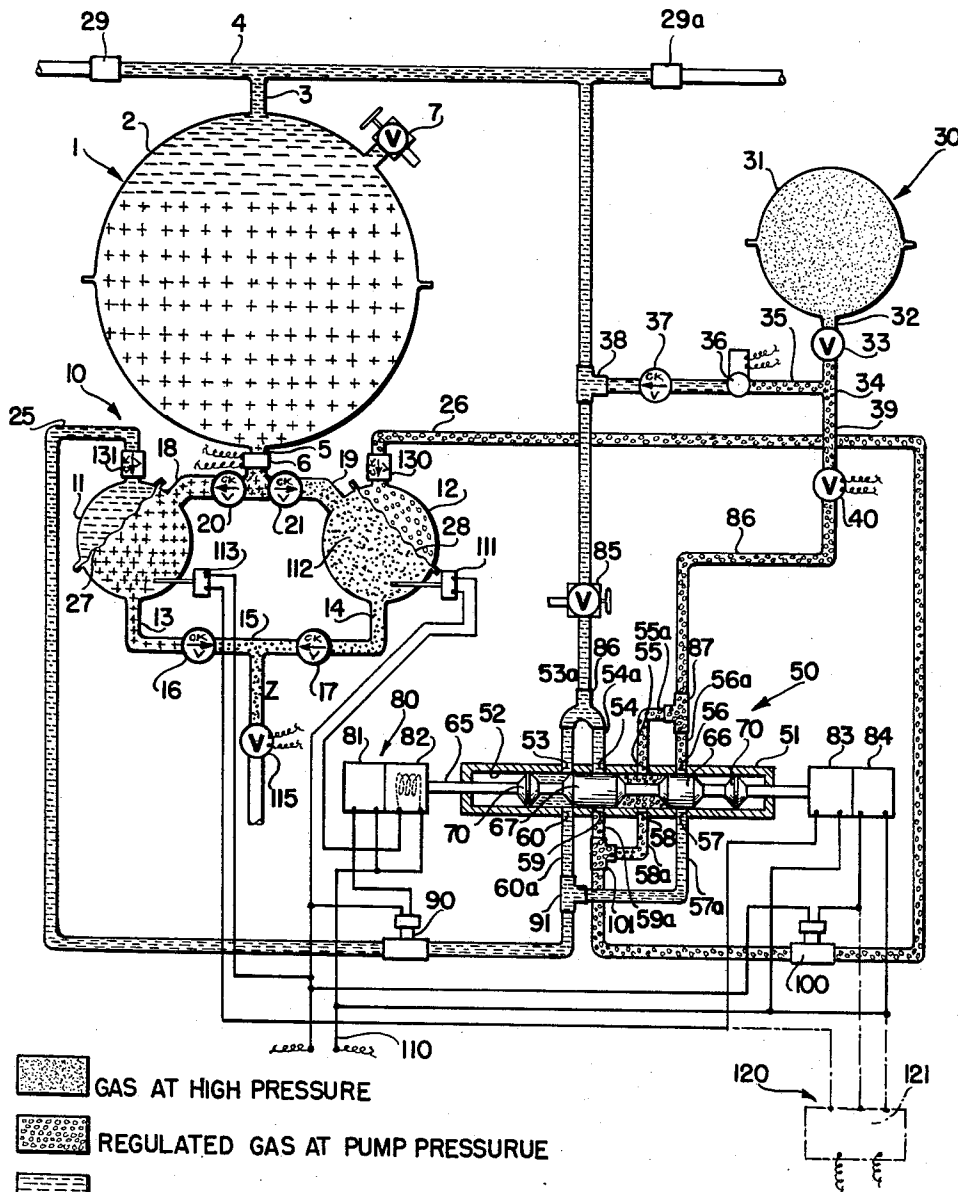
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2 Sheets-Sheet 2

Fig. 2



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3,090,325
CONTINUOUS FLOW DISPLACEMENT PUMP
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This invention relates generally to a pumping device and more specifically to a fluid pressure operated pump having particular utility in pumping volatile gases in the liquid state.

It is often necessary, especially in connection with the propulsion systems of modern ballistic or guided missiles, to provide a relatively constant supply of fluids at a given pressure. Problems are encountered when such fluids are materials which exist in the gaseous form at "normal" pressures and temperatures, and even more difficulties arise when the specific material is caustic or highly reactive and therefore dangerous to handle.

Conventional pumping systems are either not equipped to handle such reactive materials or are extremely undesirable due to their prohibitively excessive size and weight. Liquid fluorine especially is dangerous and requires delicate handling because it often reacts violently with almost any particles of foreign matter in the system. This same danger exists when a highly reactive material gets between parts rotating or otherwise moving relative to each other. Additionally, the complexity of said systems results in high manufacturing and maintenance costs and low reliability especially when flexibility and adaptability of a given unit is of primary concern.

It is accordingly a primary object of the present invention to provide a light-weight pumping system which is capable of handling highly reactive materials which must be preserved under pressure in order to maintain liquidity.

A further object of this invention is to provide a liquid pump which is extremely compact and which features an extremely light weight source of operating energy.

A further object is to provide a relatively simple pumping system requiring very few moving parts, thus eliminating friction problems and difficulties in sealing.

Another object of this invention is to provide a pumping system which is not dependent upon external sources of power such as electricity or combustion engines for motivation.

A further object is to produce a pump in which the output pressure and constancy of flow may be closely regulated to conform with the requirements of a given application.

An additional object is to provide a novel valving and sensing system which will dependably operate a pressure pump of the type disclosed and which may be remotely actuated and controlled.

Yet another object is to provide a pumping system having an interior which may be maintained in sterile condition and in which the energizing medium need not come in contact with the substance to be pumped.

A further object of this invention is to provide a relatively constant outlet pressure that will be substantially unaffected by "G" forces acting upon a high column or "head" of the material awaiting evacuation.

With these and other objects in mind, the invention will be described in detail in connection with the drawings wherein like figures denote like parts throughout and wherein,

FIGURE 1 is a cross-sectional elevational representation of the particular valve control assembly which is a feature of this invention;

FIGURE 2 is a coded schematic representation showing parts in section of a system constituting a preferred embodiment of the invention;

FIGURES 3 and 4 are cross-sectional elevation views of the valve control assembly of FIGURE 1 showing this assembly in succeeding phases of operation; and FIGURE 5 is an elevation view of one modification of a sub-chamber assembly.

First reference will be made in connection with FIGURE 2 of the drawings wherein there is shown a system in accordance with the preferred embodiment of the invention. For the purposes of describing the invention, the material to be pumped will be considered to be liquid fluorine although it should be understood that the system may be utilized in connection with other reactive materials, volatile materials normally gaseous which are pressurized in order to maintain liquid delivery, and other conventional type liquids.

Indicated generally by number 1 is a reservoir or storage assembly composed in this instance of a spherical supply tank 2 having a liquid and actuating pressure inlet 3 connected to supply line 4. At the base or lower portion of this storage tank is an outlet 5 having a cut-off valve 6 therein. This cut-off valve 6 is shown to be of the remotely controlled type although manual or automatic valves could be substituted when required by given applications.

Located in an upper enclosing surface of the tank 2, which may be cylindrical, square, rectangular, or any other shape, is an atmospheric vent valve 7 which may be used to bleed the pressure from tank 2 or vented to atmosphere in connection with a second embodiment as will be more fully described hereinbelow.

Located schematically beneath reservoir assembly 1 is a displacement or evacuation assembly generally denoted 10 which consists of a plurality of substantially identical sub-chambers 11 and 12. These sub-chambers or evacuating chambers are substantially smaller than reservoir tank 2 and may be of any desired configuration, with the spherical type shown being the most convenient. Each of these sub-chambers 11 and 12 are provided with outlet pipes 13 and 14 respectively which may preferably terminate in a T-junction at 15. Each of these outlet pipes 13 and 14 contains a one-way or check valve indicated at 16 and 17 which prevent backward or reverse flow therethrough of either liquid or gas. In the embodiment shown these check valves are adapted to allow forward passage under pressure only as will be hereinafter more fully explained. Connecting each of the sub-chambers 11 and 12 with reservoir or supply tank 2 are inlet pipes 18 and 19 associated with the outlet pipe 5 in the base of tank 2. Each of these inlet pipes 18 and 19 are provided with a one-way check valve 20 and 21 which permits the flow in one direction only of material which is passed from the supply tank 2 and also prevents the flow of fluid under pumping pressure back into tank 2. The diameter of lines 18 and 19 is larger than that of outlet lines 13, 14 to compensate for the difference in pressure affecting the rate of movement of the material being pumped.

Obviously, more than two such sub-chambers could be provided if the sensing means as at 111 and 113 were connected in parallel.

As indicated at 25 and 26, each of the sub-chambers 11 and 12 respectively is provided with an upper pressure inlet opening to allow access of equalizing and/or evacuating pressure to the sub-chambers. If desired, for utilization of the device in connection with medical practices, diaphragms 27 and 28 may be provided across these pressure inlets within each of the subchambers. These diaphragms are flexible, elastic members which expand under pressure to fill substantially the entire tank to allow evacuation thereof while preventing the evacuating fluid from contacting the material to be displaced. The valves

indicated at 29 and 29a are emergency pressure relief valves (or overload valves) and filler valves, respectively.

In place of diaphragms such as shown in FIGURE 2 of the drawing it has been found to be advantageous in some applications to provide a bellows 125 (see FIGURE 5) extending into the sub-chambers from a position wherein their inner surfaces are contactable by the energizing pressure fluid. These bellows 125 extend into the sub-chambers on a plurality of slides or guide rail members 126. Thus, dangerous splashing of the reactive fluid in the sub-chambers would be eliminated since that part of the chamber not filled with fluid at a given moment would be occupied by the bellows.

For the purpose of supplying operating pressure to the system, there is provided an energizing means generally indicated at 30. This energizing means comprises a tank 31 of any desired configuration which is adapted to withstand high internal pressures. The operating or pumping gas under high pressure is contained within tank 31 and is supplied to the system through valves which will be explained below. This gas is preferably helium when the material to be pumped is liquid fluorine, however, propellant gas may be of any type which is adaptable to furnish pumping pressures while at the same time being compatibly non-reactive with the material pumped. Located in the base of tank 31 is an outlet 32 having a pressure regulator 33 therein. As an example, in the disclosed embodiment this regulator and shut-off valve 33 is adapted to regulate the pressure of approximately 3000 p.s.i. within the tank to approximately 140 p.s.i. on the lower side thereof which is provided with a joint of the T, Y, or other type generally indicated at 34. One of the arms 35, associated with joint 34 has a "low" pressure regulator and shut-off valve 36 located therein which in this embodiment is provided to lower the pressure of 140 p.s.i. on the right hand side of the valve to a "low" or "venting" pressure of approximately 30 p.s.i. This low pressure line has a one-way check valve 37 provided therein between the pressure regulator 36 and a junction 38 connecting the line into reservoir tank 2 described above and also into the control assembly. The other arm 39 extending from junction 34 is provided with a remotely controllable pump pressure shut-off valve 40, which cooperates with shut-off valve 6 and valve 37 to start or stop the operation of the system in a manner which will be described hereinbelow.

Generally indicated at 50 is a control means consisting of a housing 51 having a chamber 52 therein. Leading into the chamber 52 through wall 51 are a plurality of, in this case eight, ports denoted by numbers 53 through 60. These ports are longitudinally spaced within the wall of housing 51 and are transversely aligned in pairs, one of said pairs being 53, 60, and another of said pairs being 55, 58.

In the preferred embodiment shown, housing assembly 51 has a longitudinally slidable valve assembly journaled therein consisting of a valve shaft 65 having port controlling enlargements 66 and 67 coaxially situated thereon. It will be seen that these enlargements are of different lengths and are so placed as to provide a sequence of opening and closing of the respective ports with which they become associated in a manner which will be described in connection with the operation phase of the system.

Additionally, valve shaft 65 has pressure buffers 70 situated at either end thereof and located on said shaft without the area of the ports in said housing. In this manner these pressure buffers will neutralize any unequal pressures entering the chamber 52 which would otherwise tend to bias the valve shaft 65 and the enlargements thereon in an adverse manner. A consideration of the valve control assembly 50 as depicted in each of the FIGURES 1 through 4 in its various positions will reveal that in any position shown the pressures acting upon the faces of the enlargements on shaft 65 are equalized resulting in

a static, neutral positioning of the slide valve assembly in connection with any chosen adjustment.

Associated longitudinally with the valve slide shaft 65 are means, located at either end of the shaft in this embodiment, for actuating the shaft as the cycle of pumping proceeds. The means shown in this preferred embodiment are indicated generally at 80 and will be seen to consist of a pair of electrically actuated solenoids located at either end of the shaft. These solenoids are numbered 81 through 84 respectively. Thus as solenoid 82 for example is actuated, the tendency would be to move the valve assembly shaft 65 to the left which would of course change the adjustment of the valve assembly 50 closing some ports and opening others. Solenoids 81, 83 and 84 are adapted to operate identically with solenoid 82 and each serve to position the slide assembly 65 in a given position.

Reference will now be given to the connection of the various ports in valve assembly 50 to the other components of the system.

As noted above, one side of junction 38 is connected to the inlet port in supply tank 2. The other side of junction 38 is provided with an atmospheric vent valve 85 and is connected through this valve to junction member 86 having connecting pipes associated with inlet ports 53 and 54, these pipes being numbered 53a and 54a respectively for convenience.

Following "pumping" pressure line 39 from pressure tank 31 and through remotely controllable valve 40 is a conduit 86 provided with a junction member 87 having arms connecting ports 55 and 56 into said pumping or intermediate pressure line. Similarly, these pipes are numbered 55a and 56a respectively.

Referring to inlet line 25 associated with sub-chamber 11, it will be seen that this line is provided with a pressure actuated electrical switch 90 which is electrically connected in series with solenoid 81. After passing through pressure switch 90, line 25 divides at junction member 91 into conduits connecting ports 57 and 60 into line 25. These connecting arms are numbered 57a and 60a respectively. It should be understood that conduit 60a associated with port 60 is substantially transversely aligned with opening or port 53 in housing 51 and in a similar manner 57a enters port 57 which is in turn substantially transversely aligned with port 56 in housing 51.

Referring now to line 26 associated with sub-chamber 12, it will be seen that line 26 passes through a pressure switch 100 connected in series with solenoid 84, substantially identical to the arrangement of pressure switch 90 and continues to junction member 101 which divides line 26 into connecting arms 59a and 58a entering ports 59 and 58 respectively in housing 51. Ports 59 and 58 are substantially transversely aligned with ports 54 and 55 respectively.

Turning now to the electrical system utilized in connection with the embodiment shown in FIGURE 2 of the invention, 110 indicates generally the electrical inlet supply which may be of any conventional type, and may be a normal supply line if the system is used on the ground or may be battery or power supplied by conventional units if utilized in aircraft, missiles, or the like.

Referring first to sub-chamber 12 it will be seen that a sensing element 111 is associated therewith. This sensing element may be any conventional type which is constituted to provide an electric circuit completion when the level of liquid 112 in sub-chamber 12 reaches a given point. Preferably this sensing element is open when the sub-chamber is filled and closes upon the level of liquid reaching a pre-set point approximately at the sensing element 111. This sensing element is connected in series with solenoid 82 on the left side of the valve control assembly 50.

In a like manner a similar sensing element 113 is associated with sub-chamber 11 and operates in identical man-

5

ner. This sensing element is connected in series with solenoid 83 on the right hand side of valve control assembly 50. The series arrangements of pressure switches 90 and 100, connected in series respectively with solenoids 81 and 84, respectively, has been noted above.

Generally indicated by broken lines in FIGURE 2 is a starting switch assembly denoted generally by number 120. This starting switch assembly consists of, for example, a DPDT switch 121 with two separate circuit arrangements connected respectively to solenoids 83 and 84. Thus, as the switch is thrown or closed in the circuit with solenoid 83, the slide valve member 65 will be drawn to the right to a position indicated in FIGURE 3 of the drawings. Upon operation of the "right hand" circuit of the starting switch solenoid 84 will be actuated pulling slide valve shaft 65 to its extreme right position shown in FIGURE 2.

Attention is directed to the coding in the lower left hand corner of the drawing in connection with FIGURE 2 wherein the contents of the system of this figure are denoted according to their pressure and types of material.

Operation

The operation of the device will now be described in connection with the figures referring originally to FIGURE 1, which is a starting position of the system. In describing the system as it is put into operation, it should be understood that the control valve assembly at 50 could be positioned with the slide valve shaft 65 positioned at the extreme right of the housing 51 in which case the sequence of events involving the starting switch would be reversed. Before starting, valves 6, 33, 36 and 40 will be in closed position.

In connection then with FIGURE 1 and superimposing the valve assembly position shown therein into the system as it appears in FIGURE 2, it will be seen that as valves 33 and 36 are opened, low pressure will be flowing through junction 38, vent valve 85 (here closed to atmosphere), through junction 86 and into arm 54a which enters inlet port 54. Exiting from the chamber at port 59 and continuing through pipe 59a, through pressure switch 100 and line 26 low pressure enters sub-chamber 12 through the inlet port and one-way liquid check valve 130 in the top portion thereof. Such liquid check valves would only be necessary when diaphragms are not utilized. Similarly proceeding from joint 38 through line 3 and into the top of storage reservoir or tank 2 an equal pressure or "venting" is admitted. In this instance atmospheric vent valve 7 is closed. Thus the pressure within both tank 2 and sub-chamber 12 is equalized and the fluid material contained within tank 2 will, on opening of valve 6 flow through check valve 21 into chamber 12.

In connection with this embodiment wherein liquid fluorine is the material to be pumped, the pressure within tank 31 is desirably approximately 3000 p.s.i. which is reduced by pressure regulator 33 from 3000 p.s.i. to about 140 p.s.i. This pressure is further reduced by valve 36 from 140 p.s.i. to approximately 30 p.s.i. which then is admitted through one-way check valve 37 and proceeds to pressurize tank 2 and sub-chamber 12.

At this particular stage valve 40 has not yet been opened and line 86 will remain clear. Therefore there will be no pressure admitted into sub-chamber 11 because the passageway or open chamber connecting port 53 with port 60 is blocked by the enlarged blocking member 67 on shaft 65. It should be noted that check valves 20 and 21 are one-way valves which are adjusted to allow the passage of fluid therethrough at or slightly below the equalizing pressure which is in this instance approximately 30 p.s.i.

It should be noted that liquid check valves 130 and 131 prevent the flow of liquid back into the pressure line when the sub-chambers become full.

The second phase of the pumping operation is illustrated in FIGURE 2. After sub-chamber 12 has been

6

filled with fluid, starting switch 121 is operated which pulls valve shaft assembly 65 to the extreme right through the operation of the solenoids 83 and 84 in consecutive operation. The valve should be positioned to the extreme right in one substantially continuous operation (without intermediate stop). At substantially the same time valve 40 is opened allowing intermediate or "pumping" pressure (at approximately 140 p.s.i. in this instance) to enter into pipe 86. This pressure then flows through junction 87 and through pipe 55a into the chamber through port 55, leaving the chamber through port 58 and arm 58a thereof, this pressure then passing through the pressure switch 100, and through line 26 into chamber 12. Since this is an evacuating or pumping pressure as noted above at approximately 140 p.s.i. the fluid contained in sub-chamber 12 is evacuated therefrom through the outlet 14, through check valve 17 and out the outlet pipe Z through valve 115. It should be noted that the slide valve assembly in this position while allowing pressure to enter and leave the chamber through ports 55 and 58 has closed the passage from ports 56, 57 and 54, 59. Consequently this pumping pressure line is only open to sub-chamber 12. As ports 54, 59 and 56, 57 were closed, ports 53, 60 were simultaneously being opened. As there is now no obstruction or blocking of the passage 53a the low or venting pressure at approximately 30 p.s.i. is permitted to enter into the chamber through arm 53a and exit therefrom through port 60, conduit 60a and through line 25 into sub-chamber 11. With this opening through the valve assembly being made, pressure is automatically equalized between sub-chamber 11 and tank 2. As the fluid in tank 2 by gravity enters into chamber 11, the pressure is displaced therefrom and is free to flow into the top of tank 2 thus allowing for an unrestricted flow of fluid.

At this point the operation of the starting switch 120 is substantially over.

When the level of liquid in sub-chamber 12 reaches a point which is slightly below sensing means 111, the circuit is closed through said sensing means which in turn actuates solenoid 82 to position the slide valve assembly as shown in FIGURE 3.

Reference to this figure will show that the ports 53 and 54 allowing low pressure to enter into the system are closed while the high pressure or pumping pressure ports 55 and 56 are open and pressure flows across the chamber to corresponding ports 58 and 57 and flows through arms 58a and 57a through lines 25 and 26 respectively into the sub-chambers 11 and 12 causing thereby an evacuating pressure to be sustained in each one of these sub-chambers. This condition when both sub-chambers are pressurized to the pumping pressure of approximately 140 p.s.i. occurs for only an instant since as soon as intermediate or pumping pressure passes through junction 91 and contacts pressure switch 90, the pressure switch becomes closed and will actuate solenoid 81 to position the valve slide assembly in a position as shown in FIGURE 4.

In FIGURE 4 the valve control assembly is shown maintaining evacuating pressure in sub-chamber 11 since the pumping pressure port 56 is open across the chamber and through port 57. Simultaneously as the slide valve 65 is moved toward the left by actuation of solenoid 81, the port 54 became open and low or venting pressure was then free to flow out through port 59, through arm 59a, through junction 101 and into line 26 where the pressure in sub-chamber 12 was again equalized with that in the supply reservoir tank 2, thus allowing sub-chamber 12 to refill.

It will be seen that this sequence of operation is repeated until the supply tank 2 is exhausted or until terminated by outside means.

Summarizing then the sequence of operation of start-

ing the system, it is necessary to open valves 6, 33, and 36. The slide valve shaft 65 is then positioned manually or by conventional remote control means (not shown) to the extreme left hand position within chamber 52. This movement will cause venting pressure to move across ports 54 and 59, venting and filling sub-chamber 12.

Next the starter switch is operated actuating solenoids 83 and 84 rapidly consecutively to pull the slide valve shaft 65 to the extreme right hand position. At approximately the same time the opening of valve 40 and the positioning of slide valve assembly as shown in FIGURE 2 will then cause an evacuating or pumping pressure to exist across ports 55 and 58, thus evacuating sub-chamber 12 while simultaneously venting sub-chamber 11 through ports 60 and 53 and back into tank 2.

Shut-off valve 115 has been provided in the outlet line Z of the system. This valve remains closed until one of the sub-chambers has been filled during the starting operation. Obviously, if valve 115 were omitted, or opened, during starting there would be no "back pressure" reacting to allow the sub-chambers to completely fill (unless such back pressure were provided by the inherent resistance of a missile engine or the like). Once one of the sub-chambers was filled the other would fill during the evacuation of the first because of the "back pressure" built up across either of valves 16 or 17. By making valve 115 a remotely controlled unit, it would be possible to "prime" or "start" the system and maintain it in a constantly operational status. Similarly the pump may be started and stopped at will from the remote control position.

It will be understood that pressure switches 90 and 100 are provided in order to maintain the non-pulsating substantially constant flow of material from the outlet pipe Z. These pressure switches may be of conventional type and are chosen in this particular embodiment to close a circuit or switch at approximately 140 p.s.i. Their function is as follows; as the level of liquid in sub-chamber 12 reaches a point wherein the sensing means 111 will be actuated, a circuit is closed operating solenoid 82 to pull the slide valve assembly shaft 65 to the left to the position shown in FIGURE 3. It will be seen in this figure that both of the sub-chambers will be evacuating at the same time. This simultaneous evacuation is necessary only until pumping pressure of approximately 140 p.s.i. is raised within, for instance, line 25 so that the filled sub-chamber 11 would then be evacuated. At the time the pumping pressure is reached, pressure switch 90 is closed actuating solenoid 81 which positions the shaft 65 as shown in FIGURE 4 wherein chamber 11 continues to evacuate while the other sub-chamber is allowed to fill because of the particular venting arrangement within the control assembly 50.

As used in this specification a "high" pressure is used to mean that pressure within the energy supplying tank 31. This pressure would exist on the pressure tank side of valve 33. On the other side of this valve a "pumping" pressure or an immediate or evacuating pressure exists. The "low" pressure will exist on the supply tank side of valve 36 which acts to reduce the pressure on the other side of said valve from 140 to approximately 30 p.s.i. in this embodiment.

Thus there is combined in a single system the advantages of having a low pressure internal feeding system and a high pressure pumping or ejection system.

It should be realized that volatile fluids of any type could be used in the system if the pressure valves and switches were calibrated in a manner to be compatible with the requirements of a given material. Thus if a particular gas required a pressure of 50 p.s.i. to maintain it in the liquid state, valve 36 would be required to be adjusted so that the tank side would be pressurized to a

pressure of 50 p.s.i. while keeping or maintaining the intermediate or pumping pressure on the other side of said valve in its condition of 140 or higher p.s.i. Similarly pressure switches 90, 100 would have to be adjusted.

In a like manner the system may be utilized in medical practices wherein it will find utility as an artificial heart, serving to pump blood from a point without the body back into the body. In this embodiment especially, diaphragms 27 and 28 would be necessary wherein they would not have been required in the systems referred to hereinabove. In a system utilized in pumping blood, it would be necessary to vent chamber 2 to the atmosphere through atmospheric vent valve 7. Likewise the atmospheric vent 85 would be opened, allowing blood to enter into tank 2 from whence it could pass to the displacing sub-chambers 11 and 12. In this case valve regulator 36 would be closed. The slide valve assembly would operate in approximately the same manner, with the vent being to atmosphere through valve 85 rather than returning it to supply tank 2 in this instance. Similarly the pressure required to pump or evacuate sub-chambers 11 and 12 would be reduced to a level conforming to the requirements of the body.

Manifestly the system is extremely adaptable to varying applications. It is extremely small and of light weight. Its components sizes vary only in accordance with the size of the supply reservoir 2 and the proportionally larger requirement of energizing chamber 31. This adaptability makes the system useful in connection with rocket and missile propulsion systems.

In this connection a significant feature of the invention is the adaptability of providing the pressure or energizing chamber 31 completely within the storage tank or reservoir 2.

While a preferred embodiment of the invention has been specifically described, it is understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art, and the invention is to be given the broadest interpretation possible within the limits of the following claims.

What is claimed is:

1. A fluid-actuated pumping system comprising a supply reservoir, a pair of evacuable subchambers each connected directly to said reservoir through a one-way check valve, a Y-pipe discharge conduit having two of its arms connected, respectively, into each of said sub-chambers through one-way check valves, a self-contained high pressure fluid energizing tank connected to said reservoir and to each of said sub-chambers, control means connected to said reservoir, said sub-chambers and said energizing tank for controlling the sequence of operation of each, and a pressure lowering regulator valve connected to said energizing tank on the input side and said reservoir and said control means on the output side thereof, said control means comprising a housing having a chamber therein, access ports providing entry into said chamber which are connected to said energizing tank, said reservoir and said sub-chambers, a valve member longitudinally, slidably journaled in said chamber, said valve member being provided with two enlarged access port blocking enlargements thereon adapted to selectively open and close said ports, whereby, as said valve member is longitudinally reciprocated, the ports connecting one of said sub-chambers with said reservoir are opened for passage of fluid as the ports connecting said energizing tank and said other evacuable sub-chamber are opened to the passage of fluid on an alternating basis, pressure buffers coaxially mounted upon said valve shaft for equalizing the pressure in said chamber as said valve is reciprocated, and electromagnetic control means actuating and controlling said valve shaft.

2. A fluid actuated pumping system as claimed in claim 1 and including sensing means in each of said sub-chambers electrically connected to said electromagnetic control means.

3. A fluid actuated pumping system comprising a supply reservoir, a pair of evacuable sub-chambers connected to said reservoir through one-way check valves, a discharge pipe having a one-way check valve therein connected to each of said evacuable sub-chambers, an energizing tank adapted to contain fluid under high pressure with an outlet pipe having a venting arm and a pumping arm connected thereto, a pressure regulator valve in said outlet pipe for lowering the high pressure in said energizing tank to a pumping pressure in said pumping arm, a low pressure regulator valve in said venting arm for lowering pumping pressure to a venting pressure, a control valve assembly comprising an elongated housing having a chamber therein, eight access ports in said housing leading into said chamber, said pumping arm and said venting arm being connected to adjacent pairs of said access ports, said venting arm also being connected to said supply reservoir, a pressure inlet in each of said sub-chambers each connected, respectively, to two non-adjacent access ports, one of the non-adjacent access port connections in each pair being juxtaposed to an access port connected to said pumping arm, and the other port of each of said non-adjacent pairs being juxtaposed to an access port connected to said venting arm, a valve shaft with port blocking enlargements thereon slidably journaled in said housing, a plurality of solenoids associated with said shaft for moving the same relative to said access ports, and liquid level sensing means within each of said sub-chambers connected to said solenoids for automatically controlling the actuation of the valve shaft within said housing.

4. A fluid actuated pumping system as claimed in claim 3 in which each of said sub-chambers contains an air tight, flexible member across its pressure inlet.

5. A fluid actuated pumping system comprising a supply reservoir, a pair of evacuable sub-chambers each directly connected to said reservoir through one-way check valves, a Y-pipe discharge conduit having two of its arms connected, respectively, into each of said sub-chambers through one-way check valves, an energizing tank adapted to contain fluid under high pressure, an outlet pipe connected to said tank through a pressure regulator

valve providing a reduced pumping pressure on the output side thereof, said pipe being divided into a venting arm and a pumping arm, a low pressure regulator valve in said venting arm for reducing pumping pressure to a venting pressure, a control valve assembly comprising an elongated housing having a chamber therein, said housing having eight access ports providing entry into said chamber, two of said ports being connected with said pumping arm, the low pressure side of said low pressure regulator in said venting arm being connected to two of said access ports and said supply reservoir, each of said sub-chambers connected to two of said remaining access ports, a valve shaft longitudinally slidably journaled in said chamber, access port blocking enlargements on said valve shaft for controlling the flow of fluid between said access ports through said housing, a pair of solenoids on each end of said valve shaft outside said housing for selectively positioning said shaft within said housing, liquid level sensing means in each of said sub-chambers electrically connected to and controlling the operation of said solenoids, and a pair of pressure actuated switches located in the lines connecting said sub-chambers with said valve assembly, each of said switches being connected to at least two of said solenoids.

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