Jan. 5, 1965 G. VAN NEDERYNEN 3,164,101

DIAPHRAGM PUMP

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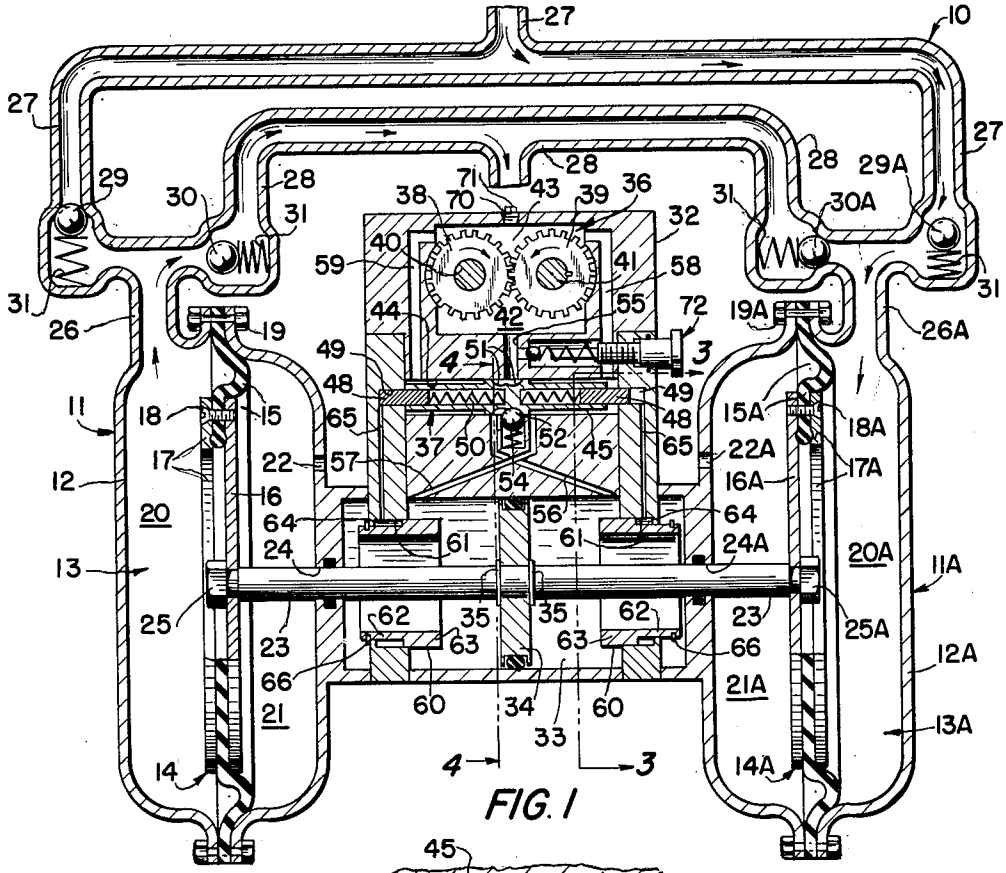


FIG. 1

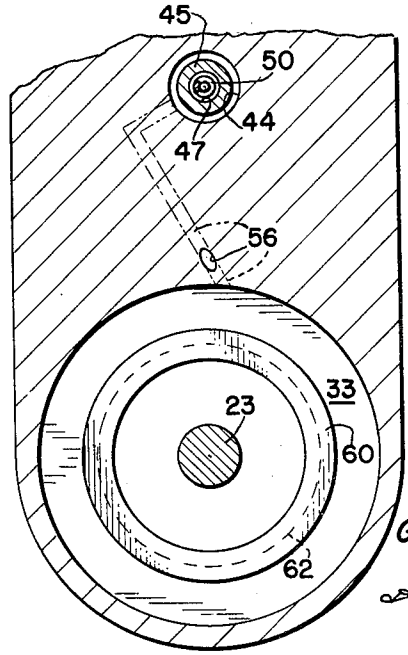


FIG. 3

INVENTOR
GERRIT VAN NEDERYNEN
BY
ATTORNEY

Jan. 5, 1965 G. VAN NEDERYNEN 3,164,101

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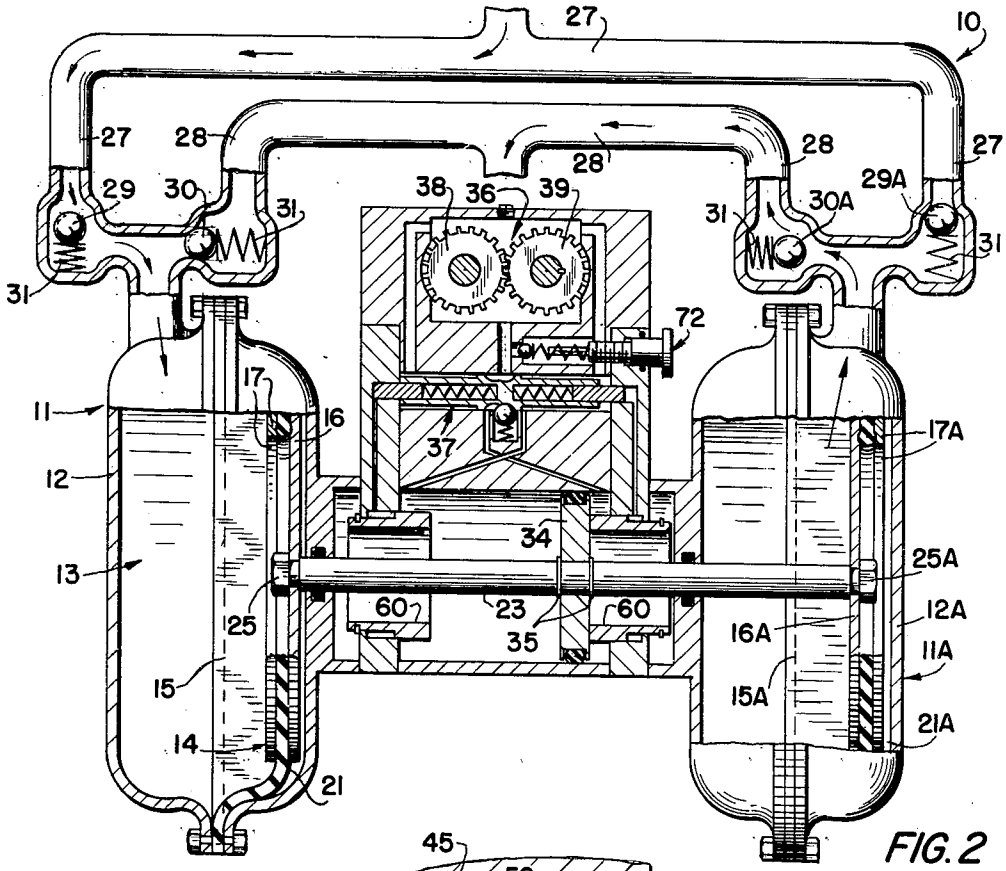


FIG. 2

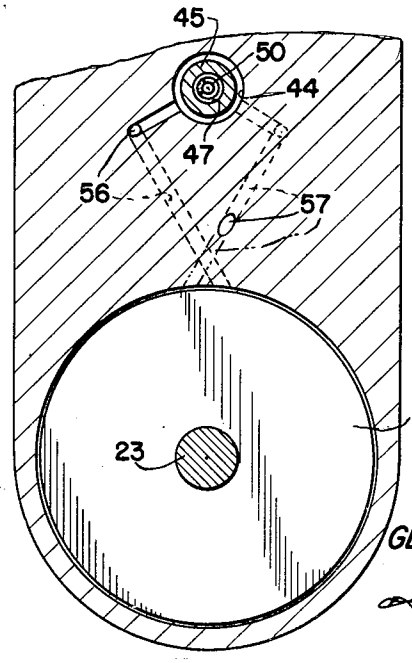


FIG. 4

INVENTOR
GERRIT VAN NEDERYNEN
BY
Arthur Frederick
ATTORNEY

Jan. 5, 1965 G. VAN NEDERYNEN 3,164,101

DIAPHRAGM PUMP

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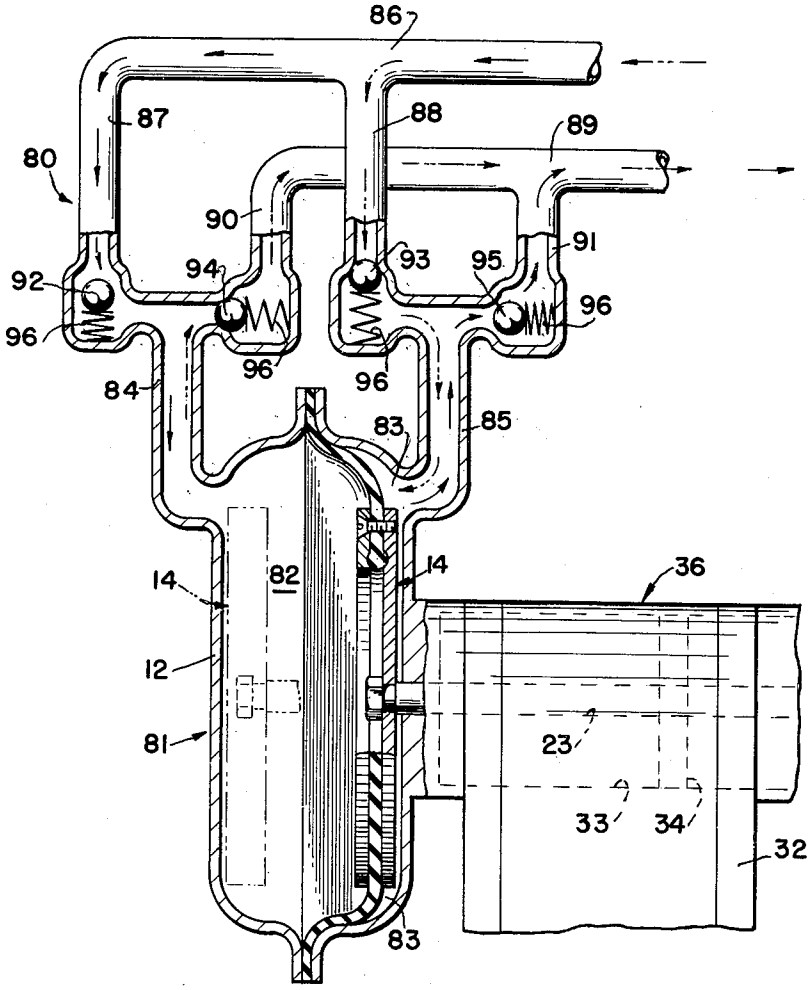


FIG. 5

INVENTOR
GERRIT VAN NEDERYNEN
BY
ATTORNEY

Jan. 5, 1965 G. VAN NEDERYNEN 3,164,101

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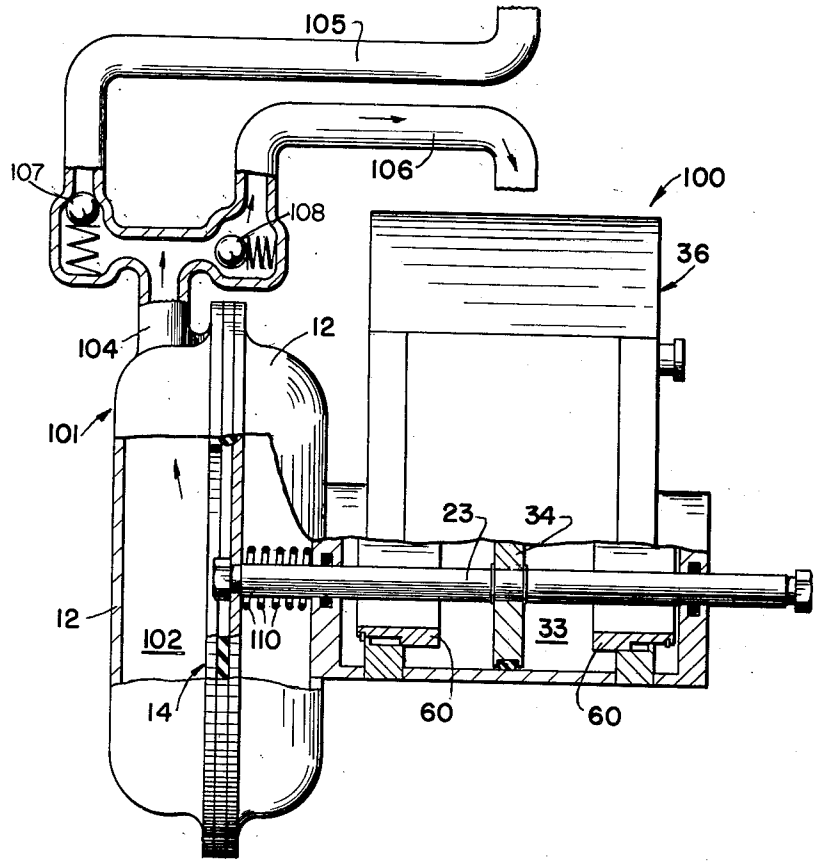


FIG. 6

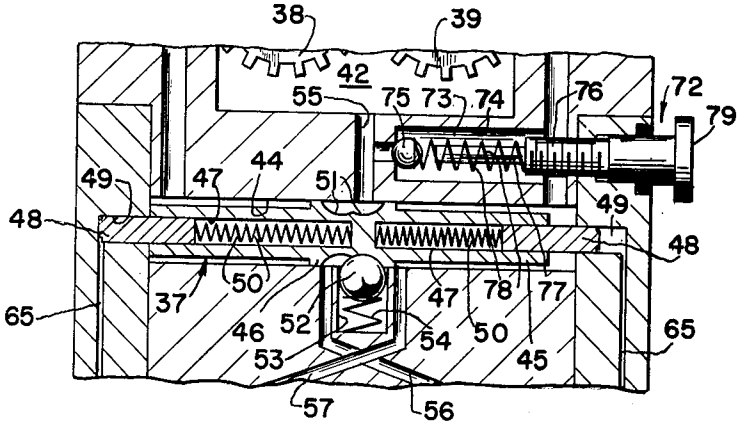


FIG. 7

INVENTOR
GERRIT VAN NEDERYNEN
BY
ATTORNEY

United States Patent Office 3,164,101 Patented Jan. 5, 1965

3,164,101

DIAPHRAGM PUMP

Gerrit Van Nederynen, Sayre, Pa., assignor to Ingersoll-Rand Company, New York, N.Y., a corporation of New Jersey

Filed Sept. 27, 1962, Ser. No. 226,666
10 Claims. (Cl. 103—152)

This invention relates to pumps and more particularly to diaphragm type pumps.

In diaphragm pumps wherein the diaphragm or diaphragms are actuated by reciprocation of a diaphragm connecting rod, the electrical or internal combustion motors from which the pump derives its power are usually connected through mechanical linkages or cranks to the diaphragm connecting rod to convert the rotary motion of the motors into reciprocating motion of the diaphragm connecting rod. Usually the motors are designed to operate at a relatively constant speed so that the driving force imparted to the diaphragm connecting rod during each stroke of the latter varies from a minimum value, equal to the motor torque divided by the crank throw, to infinity depending upon the angular position of the crank. However, the force required during each stroke of the diaphragm connecting rod to displace the fluid being pumped through the discharge line of the pump, after the fluid has been accelerated, is constant. Since the constant force necessary to pump the fluid during each stroke or actuation of the diaphragm should never exceed the minimum force that the crank is capable of transmitting to the diaphragm connecting rod, the pumps are designed to utilize the minimum crank force which results in nonuse of the force in excess of the minimum crank force which the crank is capable of producing. Thus, such pumps are relatively inefficient.

It is, therefore, an object of the present invention to provide a diaphragm pump which is more efficient over a wide range of discharge pressures than heretofore known diaphragm pumps.

Another object of this invention is to provide a diaphragm pump capable of being easily adjusted to various pumping requirements.

A further object of the present invention is to provide in a diaphragm pump a diaphragm actuating means of relatively simple construction.

A still further object of this invention is to provide, in a diaphragm pump, a safety device to prevent damage to the pump or motor in the event of overloading or jamming of the pump.

The present invention, therefore, contemplates a novel diaphragm pump comprising at least one diaphragm fixedly secured at its periphery in a casing forming an actuating chamber. Valved inlet and outlet means are connected to the casing to provide for passage of fluid to be pumped into and out of the working chamber upon actuation of the diaphragm.

A fluid actuating means is provided to effect actuation of the diaphragm. The fluid actuating means includes a connecting rod suitably supported in the casing for reciprocation to cause actuation of the diaphragm alternately in one direction and then the opposite direction and thereby effect pumping of the fluid to be pumped through the inlet and outlet connections. The connecting rod is constructed and arranged to extend coaxially through a piston chamber disposed adjacent to the actuating chamber formed by the diaphragm casing. A piston means is secured to the connecting rod and disposed for reciprocation in the piston chamber. A fluid pump, of the constant or variable displacement type, such as a gear or multi-vane type pump, is provided along with a valve control means to alternately supply high pressure fluid to

opposite sides of the piston to thereby effect reciprocation of the connecting rod.

The fluid pump is driven by direct connection, or through a simple speed reduction mechanism, to a prime mover, such as an electric motor or internal combustion engine.

A further feature of the present invention is a safety means constructed and arranged in cooperative relationship with the fluid pump to by-pass high pressure fluid around the piston cylinder in the event of overloading or jamming of the diaphragm pump.

In one embodiment of the invention the diaphragm pump comprises two diaphragms connected to opposite ends of a connecting rod with each diaphragm having suitable valved inlet and outlet means for providing flow of fluid to be pumped.

In another embodiment of the invention the diaphragm pump comprises a single diaphragm with suitable inlet and outlet means connected to communicate with the actuating chamber on each side of the diaphragm so as to provide fluid discharge in each direction of actuation of the diaphragm.

In a further embodiment of the invention the diaphragm pump comprises a single diaphragm with inlet and oulet means connected to communicate with the actuating chamber only on one side of the diaphragm so as to provide fluid discharge only in one direction of actuation of the diaphragm. In addition, mechanical means may be provided for biasing the diaphragm in the direction of the discharge stroke of the diaphragm.

The invention will be more fully understood from the following detailed description thereof when considered in connection with the accompanying drawings wherein several embodiments of the invention are illustrated by way of example, and in which:

FIG. 1 is a sectional view of the diaphragm pump according to one embodiment of the present invention;

FIG. 2 is a view similar to FIG. 1 showing another operative position of the components of the diaphragm pump;

FIG. 3 is a transverse sectional view taken substantially along line 3—3 of FIG. 1 looking in the direction of the arrows;

FIG. 4 is a transverse sectional view taken substantially along line 4—4 of FIG. 1 looking in the direction of the arrows;

FIG. 5 is a view, partly in section, showing another embodiment of this invention;

FIG. 6 is a view, similar to FIG. 5, showing a still further embodiment of the present invention; and

FIG. 7 is an enlarged fragmentary view, in cross section, of the control valve and safety device which form a part of this invention and are shown in FIGS. 1 and 2.

Referring now to the drawings and more specifically FIGS. 1 to 4, the reference numeral **10** generally designates the diaphragm pump according to one embodiment of this invention. Diaphragm pump **10** comprises a pair of diaphragm pump subassemblies **11** and **11A** disposed in spaced parallel relationship to each other. Since the diaphragm pump sub-assemblies **11** and **11A** are identical in construction, only the pump sub-assembly **11** shown to the left of the center line of the diaphragm pump assembly **10**, as viewed in FIG. 1, will be described in detail, and like parts of diaphragm pump sub-assembly **11A** will be given like reference numerals with the suffix A.

Diaphragm pump sub-assembly **11** comprises a housing **12** having two substantial dish-shaped parts joined together to define a chamber **13** in which is disposed a flexible diaphragm **14**. Diaphragm **14** may be of conventional construction and is herein illustrated as consisting of an annular flexible member **15** clamped along

the inner peripheral edge portion thereof between a disk 16 and an annular ring 17, the ring being secured to the disk 16 by a plurality of circumferentially spaced screws 18 (only one of which is shown in FIG. 1). The outer peripheral edge portion of flexible member 15 is clamped in a fluid tight manner between the two dish-shaped housing parts by a plurality of circumferentially spaced bolts 19 so that the diaphragm divides chamber 13 into a working or pumping chamber 20 and an atmospheric chamber 21, the latter chamber being in communication with the ambient atmosphere through a port 22 in the wall of housing 12. To actuate the diaphragms 14 and 14A within chambers 13 and 13A, respectively, the diaphragms 14 and 14A are secured to the opposite ends of a connecting rod 23 which is supported for reciprocation in aligned bores 24 and 24A formed in the wall of housings 12 and 12A. The opposite end portions of connecting rod 23 are of reduced diameter so as to pass through centrally located holes in disks 16 and 16A and are threaded to receive nuts 25 and 25A to secure each of the diaphragms to the connecting rod.

Introduction and discharge of fluid to be pumped into and from each of the diaphragm pump sub-assemblies 11 and 11A is provided for by conduits 26 and 26A which are connected at one end to housings 12 and 12A, respectively, to communicate with the respective working chambers 20 and 20A of the diaphragm pump sub-assemblies 11 and 11A. The opposite end of each of the conduits 26 and 26A is connected to an inlet conduit 27 and a discharge conduit 28. A pair of check valves 29 and 29A of conventional type, such as ball type check valves, is disposed in inlet conduit 27 adjacent conduits 26 and 26A to control flow of fluid to be pumped into conduits 26 and 26A and the respective working chambers 20 and 20A. A pair of check valves 30 and 30A, similar to check valves 29 and 29A, is provided in discharge conduit 28 adjacent conduits 26 and 26A to control flow of pumped fluid from working chambers 20 and 20A through conduits 26 and 26A. Each of the check valves 29, 29A, 30 and 30A is provided with a spring 31 to bias the valves in a closed position. The check valves cooperate with each other and are responsive to actuation of diaphragms 14 and 14A to alternately provide flow of fluid from inlet conduit 27 into one of the working chambers 20 or 20A of the diaphragm pump sub-assemblies 11 and 11A and discharge fluid from the other working chamber into discharge conduit 28.

Disposed between and suitably connected to diaphragm pump sub-assemblies 11 and 11A is a fluid actuating means for effecting reciprocation and hence the actuation of diaphragms 14 and 14A. The fluid actuating means comprises a housing 32 which is constructed and arranged to provide a cylindrical piston chamber 33 located concentric with the longitudinal axis of connecting rod 23. A piston 34 of any suitable construction is secured to connecting rod 23, substantially mid-way of its length, as by a pair of retaining rings 35. To provide for alternate flow of fluid under pressure to the piston chamber 33, first on one side of piston 34 and then to the opposite side of the piston to effect reciprocation of connecting rod 23, a fluid pump 36, a control valve 37, and suitable passageways are provided in housing 32, as hereinafter more fully described.

Fluid Pump

Fluid pump 36 may be of the constant or variable displacement type, such as a gear pump, or a multi-vane pump. For illustration purposes, fluid pump 36 is shown as a gear pump having two intermeshing gears 38 and 39 secured to shafts 40 and 41, respectively, for rotation. Gears 38 and 39 are disposed in a pump chamber formed within housing 32 so as to divide the pump chamber into a high pressure section 42 and a low pressure section 43. A prime mover (not shown) such as an electric motor, internal combustion engine or the like, is connected either directly or indirectly through a simple gear reduction mechanism (not shown) to shaft 40 and/or shaft 41 to rotatively drive the latter and thus rotate gears 38 and 39.

Fluid pump 36 may also be a pressure compensated pump of the piston, gear or vane type. This type of pump is capable of sensing the output pressure of the fluid in high pressure section 42 and, as the pressure decreases, the pump automatically delivers a greater volume of fluid so that the work output remains substantially constant regardless of the output pressure or head against which the diaphragm pump assembly works.

Control Valve

As best shown in FIG. 7, a control valve 37 for controlling flow of pressurized fluid from fluid pump 36 to piston chamber 33, is disposed within a bore 44 formed within the housing 32 between fluid pump 36 and piston chamber 33. Control valve 37 comprises an elongated cylindrical body 45 having a central portion 46 of enlarged diameter adapted to slidably engage the peripheral surface of bore 44. The body 45 is of a length shorter than the length of bore 44 so as to permit axial slidable movement of body 45 within bore 44. Axial recesses 47 are provided in body 45 extending inwardly from the opposite ends of the body. A piston 48 is disposed to partly extend into each of the recesses 47 and a bore 49 arranged coaxial to and adjacent each of the ends of body 45. A spring 50 is disposed in each of the recesses 47 to bias each of the pistons 48 in a direction toward their associated bores 49. To provide the control valve 37 with rapid or "snap action," the central portion 46 of body 45 is provided with two annular, semiarcuate recesses 51 which are adapted to receive a portion of a ball 52. Ball 52 is disposed partly in a hole 53 and is biased by a spring 54 to engage recesses 51 in body 45 of the control valve.

Fluid Flow Passageways

To provide for flow of pressurized fluid from the high pressure section 42 of fluid pump 36, a passageway 55 is provided which extends from communication with high pressure section 42 to bore 44 and into communication with recesses 51. With the control valve in the position as shown in FIG. 1, a passageway 56, formed in housing 32, is in communication at one end with passageway 55, through one of the annular recesses 51, and at the opposite end with piston chamber 33 to the right of piston 34 as viewed in FIG. 1. A passageway 57, similar to passageway 56, is provided, which passageway, in the position of control valve 37 as shown in FIG. 1, communicates at one end with piston chamber 33 to the left of piston 34 as viewed in FIG. 1 and at the opposite end with bore 44 and the annular chamber formed between body 45 of the control valve and the peripheral surface of bore 44. In the control valve position as illustrated in FIG. 1, high pressure fluid is conducted to chamber 33 to the right of piston 34 by way of passageway 56 to force piston 34 in a direction to the left as viewed in FIG. 1, while passageway 57 conducts low pressure fluid, as piston 34 moves in a direction to the left out of chamber 33, into bore 44. To return this low pressure fluid to the low pressure section 43 of fluid pump 36, a return conduit 58 is disposed to communicate at one end with bore 44 and at the opposite end with low pressure section 43. A second return conduit 59, similar to conduit 58, is provided to communicate at one end with low pressure section 43 of fluid pump 36 and at the other end with bore 44 so that, when control valve 37 is in a position to the right of that shown in FIG. 1, spent pressurized fluid in chamber 33 to the right of piston 34 will be conducted from the chamber through passageway 56, bore 44 and conduit 59, to low pressure section 43.

To provide for automatic actuation of control valve 37, tubular piston members 60 are disposed at opposite

ends of piston chamber 33 in openings 61 which are formed in housing 32 coaxial with chamber 33. Each of the piston members 60 is provided with a reduced diameter portion 62 which is slidably receivable in opening 61, and an enlarged portion 63 which is slidably receivable in a counterbored portion of opening 61. The adjacent peripheral surfaces of the piston member 60 and opening 61 between the respective shoulders formed by the reduced diameter portion 62 of piston member 60 and the counterbored portion of opening 61 define therebetween an annular pressure chamber 64. To communicate each pressure chamber 64 with one of the bores 49, a passageway 65 is formed in housing 32. A retaining ring 66 is disposed in an annular groove formed in the periphery of the piston member 60 adjacent the reduced diameter end portion 62 to limit the movement of piston members 60 inwardly toward the center of piston chamber 33. The opposite or outward movement of piston members 60 is limited by the latter's abutment against the wall of housing 12 and 12A. Piston members 60 function to compress the fluid entrapped in annular pressure chamber 64 and passageway 65, when the piston members are moved axially outwardly under the urging of piston 34 after contact of the latter against the piston members during the latter part of the stroke of piston 34.

In operation of the pump, piston members 60 cooperate with control valve 37 as follows: When the fluid in chamber 64 and passageway 65 is pressurized by movement of piston member 60, the fluid exerts a pressure against the end of piston 48 in a direction to compress spring 50. The pressure exerted on piston 48 compresses spring 50 until the energy stored in spring 50 is sufficient to overcome the force exerted by ball 52, through spring 54, against the annular recess 51 in body 45 of control valve 37 and the slight frictional forces between control valve 37 and bore 44. When the energy stored in spring 50 overcomes the force exerted by ball 52 against control valve 37 and the frictional forces resisting movement, spring 50 moves body 45 of the control valve causing ball 52 to be depressed against the tension of spring 54 and the body 45 to "snap" into the next adjacent recess 51 of the control valve to hold the latter in this other position. After control valve 37 has moved to a new position, the tubular piston member 60 is returned to its normal position under the urging of fluid pressure in chamber 64 as spring 50 forces piston 48 back into bore 49.

The pressurized fluid for fluid pump 36 is introduced into housing 32 through a filler port 70. Since the above described fluid actuating means which includes pump 36, is a closed cycle system where the fluid is recirculated to fluid pump 36 after it performs work by actuating piston 34, the filler port 70 is closed by a plug 71 which may be removed to introduce make-up fluid into the actuating means to compensate for possible loss of fluid due to leakage. Low pressure chamber 43 is vented to atmosphere by suitable means (not shown), such as by a vent hole in plug 71.

Fluid pump 36 may be provided with a reserve fluid chamber (not shown) which communicates through a suitable passageway (not shown) with low pressure chamber 43 to provide a reserve of fluid to compensate for possible fluid loss during operation of the pump. The filler port 70 may be disposed to communicate with the reserve fluid chamber so that make-up fluid is introduced initially into the latter.

Operation

To operate the diaphragm pump 10, the prime mover (not shown) is set into operation by conventional means (not shown), depending upon the prime mover employed. The prime mover drives gears 38 and 39 of fluid pump 36 through shafts 40 and 41. Rotation of gears 38 and 39 pumps fluid from high pressure section 42 into and through passageway 55. Assuming the control valve 37 is in the position shown in FIG. 1, pressurized fluid from passageway 55 flows into and through passageway 56, via an annular recess 51 in body 45 of control valve 37. The pressurized fluid then flows from passageway 56 into piston chamber 33 to thereby force piston 34 to move to the left as viewed in FIG. 1. The fluid in piston chamber 33 to the left of piston 34 as viewed in FIG. 1 is forced by movement of piston 34, through passageway 57 and thence into bore 44, via the annular chamber defined by the peripheral surface of the bore and the spaced outer surface of the reduced end portion of the valve body 45. From bore 44, the low pressure or spent fluid flows through return conduit 58 to the low pressure section 43 of fluid pump 36.

As the piston 34 approaches the end portion of its stroke to the left as viewed in FIG. 1, it impinges against tubular piston 60 disposed in the left hand side of chamber 33. The tubular piston 60 under the urging of piston 34 is moved to the left as viewed in FIG. 1. This movement of tubular piston 60, tends to compress fluid in chamber 64 and passageway 65, which fluid acts against the end of piston 48 in the left hand end of control valve 37 to move piston 48 axially against the tension of spring 50 associated with piston. When, as previously described, the force stored in spring 50 exceeds the force exerted upon the valve body 45 by the spring loaded ball 52 and the frictional forces resisting movement of the control valve, the control valve will "snap" to the right as viewed in FIG. 1, with the ball 52 being forced out of the recess 51 and into the next adjacent recess 51. This movement of control valve 37 in a direction to the right simultaneously seals passageway 55 from passageway 56 and brings the latter into communication with bore 44 and return conduit 59. In addition, such movement of control valve 37 simultaneously seals passageway 57 from bore 44 and return conduit 58 and effects communication between passageway 55 and passageway 57. In this aforedescribed control valve position, pressurized fluid from high pressure section 42 flows into piston chamber 33 to the left of piston 34 as viewed in FIG. 1, via passageway 55, recess 51 and passageway 57. The flow of pressurized fluid into chamber 33, from passageway 57, forces the piston to move to the right as viewed in FIG. 1 and into impingement with the tubular piston 60 disposed in the right hand side of piston chamber 33 as viewed in FIGS. 1 and 2. As shown in FIG. 2, piston 34 has already sufficiently moved piston 60 to cause fluid in chamber 64 and passageway 65 to effect movement of piston 48, in the right hand end of the control valve, to the left as viewed in FIGS. 1 and 2 and compression of spring 50 sufficiently to "snap" control valve 37 to the left. In this position of control valve 37, passageway 56 is again in communication with passageway 55 to provide flow of pressurized fluid into piston chamber 33 to the right of piston 34 as viewed in FIGS. 1 and 2, and thereby effect movement of piston to the left as viewed in the figures. In the aforedescribed manner, piston 34 is reciprocated in piston chamber 33; and since the piston is secured as by key 35 to connecting rod 23, rod 23 is reciprocated.

Reciprocation of connecting rod 23, actuates diaphragms 14 and 14A in their respective chambers 13 and 13A. As viewed in FIG. 1, movement of connecting rod 23 in a direction to the left, forces diaphragm 14 to move to the left and thereby forces fluid to be pumped out of working chamber 20, through conduit 26, past ball valve 30, and into discharge conduit 28 for delivery to the point of use. The pressure of the fluid in working chamber 20, as it is displaced by diaphragm 14, unseats ball valve 30 against the tension of its spring 31. At the same time, the fluid pressure assists spring 31 in holding ball valve 29 seated in a closed position. Simultaneous with the movement of diaphragm 14, diaphragm 14A moves

to the left, as viewed in FIGS. 1 and 2, within atmospheric chamber 21A. This movement or suction stroke, draws fluid to be pumped into working chamber 20A, past ball valve 29A, and through conduit 26A from intake or supply conduit 27. Valve 30A, in discharge conduit 28, is seated in a closed position under the urging of its spring 31 and the fluid pressure in discharge conduit 28. Upon movement of connecting rod 23 to the right as shown in FIG. 2, diaphragm 14A is forced into working chamber 20A to force the fluid to be pumped out of the working chamber, through conduit 26A, past ball valve 30A, and into and through discharge conduit 28. Simultaneously, fluid to be pumped is drawn into working chamber 20 by movement of diaphragm 14 into atmospheric chamber 21. The fluid is drawn into working chamber 20 from fluid supply conduit 27, past valve 29, and through conduit 26. Thus, reciprocation of connecting rod 23 actuates diaphragms 14 and 14A within their respective housings 12 and 12A so that each diaphragm, of pump sub-assemblies 11 and 11A through check valves 29, 30, 29A and 30A, is alternately charged with fluid to be pumped through supply conduit 27 and displaces the charged fluid through discharge conduit 28. In addition, a relatively constant discharge of fluid is achieved since as one pump sub-assembly is being charged the other is discharging pumped fluid.

Safety Device

The diaphragm pump 10 may be provided with a safety means, as shown in FIGS. 1 and 2, disposed between passageway 55 and return conduit 58 to recirculate fluid in the event the fluid pressure exceeds a predetermined pressure which would be a value just below the capacity of the prime mover (not shown) driving fluid pump 36. As illustrated in FIGS. 1 and 2, the safety means may be an adjustable spring loaded regulating valve 72. As best shown in FIG. 7, a bore 73 is provided in housing 32 extending between passageway 55 and return conduit 58. Bore 73 has a counterbored portion 74 which extends from return conduit 58 to a point short of passageway 55. A ball 75 is disposed to normally rest against a seat formed at the juncture of bore 73 and counterbored portion 74 to seal passageway 55 from return conduit 58. An adjusting member, having a threaded body 76 and a reduced diameter stem portion 77, is receivable in a threaded bore in housing 32 so that stem portion 77 extends coaxially within counterbored portion 74 of bore 73. A spring 78 is disposed over stem portion 77 of the adjusting member and, at one end, butts against ball 75 and, at the opposite end, against a shoulder formed at the juncture of the stem portion 77 and threaded body 76 to thereby bias ball 75 in a seated position. To provide for adjustment of the tension of spring 78, the adjusting member is provided with a finger knob 79. By turning knob 79, adjustment member is moved in or out of housing 32 to increase or decrease the tension of spring 78 and thereby adjust regulating valve 72 for a selected predetermined pressure at which ball 75 will unseat.

In the operation of the regulating valve 72, ball 75 is normally seated to prevent by-pass of high pressure fluid to return conduit 58. However, if the discharge conduit 28 is accidentally closed, the designed maximum discharge head is exceeded, or if the diaphragm pump 10 becomes accidentally jammed with contaminants or other entrained matter in the fluid being pumped, which conditions will cause a build-up of pressure in passageway 55, ball 75 will unseat when the pressure in passageway 55 exceeds a predetermined pressure as determined by adjustment of the tension of spring 78. With ball 75 unseated, passageway 55 is brought into communication with return conduit 58, thereby allowing fluid to flow from passageway 55 to conduit 58 and back to fluid pump 36. By recirculation of high pressure fluid back to fluid pump 36 through return conduit 58, high pressure fluid by-passes piston chamber 33 so that operation of diaphragm pump 10 ceases and prevents damage to the prime mover (not shown) and/or other components of the diaphragm pump.

In FIG. 5 is shown another embodiment of the diaphragm pump according to this invention. The diaphragm pump 80 illustrated in FIG. 5 differs from the embodiment shown in FIGS. 1 to 4 and 7 in that it is provided with only one diaphragm pump subassembly 81. The fluid actuating means, including connecting rod 23, piston 34, fluid pump 36, control valve 37, and a suitable prime mover (not shown), for effecting actuation of diaphragm pump sub-assembly 81 is the same as described in the embodiment of FIGS. 1 to 4 and 7, except that the fluid actuating means has been inverted merely to provide clearance for fluid connections to the diaphragm sub-assembly 81. In addition, the construction of the diaphragm is the same as diaphragms 14 or 14A of the previously described embodiment. Therefore in FIG. 5, component parts of diaphragm pump 80 corresponding to component parts of diaphragm pump 10 will be identified by the same reference numerals.

In diaphragm pump 80, diaphragm 14 of diaphragm pump sub-assembly 81 divides the actuating chamber formed by housing 12 into two working or pumping chambers 82 and 83. A conduit 84 is connected to housing 12 so as to communicate with working chamber 82 and provide flow of fluid into and out of chamber 82. A conduit 85, similar to conduit 84, is connected to housing 12 so as to communicate with working chamber 83 and provide flow of fluid into and out of chamber 83. To supply fluid to be pumped from a suitable source thereof, a fluid supply line 86 is connected at one end to the source of fluid (not shown) and through branch lines 87 and 88 to conduits 84 and 85, respectively. To deliver pumped fluid to a point of use (not shown), a discharge line 89 is connected through branch lines 90 and 91 to conduits 84 and 85, respectively, and to the point of use (not shown). Check valves 92, 93, 94 and 95 which may be of the ball type, as shown, are disposed in branch lines 87, 88, 90 and 91, respectively, to alternately permit flow of fluid into and from working chambers 82 and 83. Each of the check valves 92, 93, 94 and 95 is biased in a closed position by a spring 96.

In operation of diaphragm pump 80, connecting rod 23 is reciprocated as described in the embodiment shown in FIGS. 1 to 4. Upon reciprocation of connecting rod 23, diaphragm 14 is actuated in housing 12 of diaphragm pump sub-assembly 81. When, as shown in FIG. 5, diaphragm 14 is actuated from the broken line position to the position shown in solid lines, fluid in working chamber 83 is forced therefrom, through conduit 85, past check valve 95 which has been unseated by the pressure of the fluid, and into and through branch line 91 and discharge line 89, as indicated by the solid line arrows. Simultaneously, fluid is drawn from supply line 86, branch line 87, past check valve 92 which has been unseated by reason of the differential pressure across the ball of the check valve, and thence through conduit 84 into working chamber 82, as shown by the solid line arrows. Upon movement of diaphragm 14 from the solid line position as shown in FIG. 5 to the broken line position, fluid drawn into working chamber 82, as above described, is forced through conduit 84, past check valve 94 which is forced open by the fluid pressure, and thence through branch line 90 into discharge line 89, as indicated by the broken line arrows. Simultaneously, fluid to be pumped is drawn into working chamber 83 through conduit 85, past check valve 93 which has been forced open by the differential pressure across the ball of the check valve, branch line 88, and supply line 86, as indicated by the broken line arrows. In the aforedescribed manner, fluid is alternately drawn into and discharged from each of the working chambers 82 and 83 upon each reciprocation of piston 34.

In FIG. 6 is shown a still further embodiment of the

present invention which is similar to that shown in FIG. 5 in that the diaphragm pump **100** has only one diaphragm pump sub-assembly **101**. Diaphragm pump **100**, however, differs from the embodiment shown in FIG. 5 in that it has only one working or pumping chamber **102** instead of two, with the other chamber **103** formed by the diaphragm **14** being in communication with the atmosphere through a suitable port (not shown) in housing **12**. Since there is only one working chamber **102**, only one conduit **104** is connected to the housing and to a supply line **105** and discharge line **106**. As shown in the previous embodiments, check valves **107** and **108**, such as spring loaded ball valves, are disposed in supply line **105** and discharge line **106** to control flow of fluid alternately into and from working chamber **102** upon actuation of diaphragm **14**.

Diaphragm pump **100** with a fluid pump **36** of the pressure compensated type provides a relatively slow discharge stroke and a relatively fast suction stroke by reason of the difference in pressure against which the diaphragm must work on suction and discharge strokes.

The diaphragm pump **100**, shown in FIG. 6, may be provided with a spring **110** disposed around connecting rod **23** and between diaphragm **14** and housing **12**. Spring **110** permits utilization of more of the available fluid pump force by storing energy as it is compressed on the suction stroke and releasing that stored energy upon the discharge stroke and thereby providing a greater discharge pressure or head than is possible if the spring were omitted.

The diaphragm pump **100** operates in the same manner as described with respect to one of the diaphragm pump sub-assemblies shown in FIGS. 1 to 4 and therefore it is believed unnecessary to describe its operation. The component parts of diaphragm pump **100** corresponding to the same component parts as in the preceding embodiments have been identified by the same reference numerals.

It is, therefore, believed readily apparent that the present invention provides a diaphragm pump of greater efficiency than heretofore known diaphragm pumps since a substantially greater amount of the total output of the prime mover is utilized on the discharge stroke of the diaphragm. In effect this permits the use of a prime mover under theoretical conditions of about 37.5% less capacity for the same pump output requirements than diaphragm pumps of conventional construction. In addition the invention provides a diaphragm pump which is substantially smaller in size, weight and cheaper in cost than heretofore known pump of the diaphragm type. Furthermore, the diaphragm pump has an automatic safety device which prevents accidental damage to the diaphragm or diaphragms, the prime mover, and other component parts, by pressures in excess of the designed maximum discharge pressure or head, jamming resulting from contaminants in the fluid being pumped, or unintentional closing of the discharge line.

The present invention also provides where a fluid pump of the pressure compensated type is employed, a diaphragm pump capable of providing a substantially constant work output regardless of the output head or pressure against which the pump must work. This type of diaphragm pump assembly is particularly well suited for application to portable pump equipment where the output head may vary with the place of use.

Although several embodiments of the invention have been illustrated and described in detail, it is to be expressly understood that the invention is not limited thereto. Various changes can be made in the arrangement of parts without departing from the spirit and scope of the invention, as the same will now be understood by those skilled in the art.

I claim:

1. A pump comprising

(*a*) at least one pumping means including a housing and a fluid displacement means disposed for actuation in said housing,

(*b*) supply means communicating with the interior of said housing for conducting fluid to be pumped to said housing,

(*c*) discharge means communicating with the interior of said housing for conducting pumped fluid out of said housing, and

(*d*) fluid actuating means for actuating said fluid displacement means within said housing to cause fluid to be drawn into said housing through said supply means and to force fluid from said housing through said discharge means,

(*e*) said fluid actuating means including

(1) a fluid pump to provide fluid under pressure,

(2) a control means responsive to fluid pressure for actuation from one position to another for controlling flow of fluid under pressure so as to effect actuating of said fluid displacement means and thereby alternately draw fluid to be pumped into said housing and discharge said fluid from the housing,

(3) means forming a fluid chamber,

(4) passage means communicating said fluid chamber with said control means, and

(5) piston means disposed for slidable movement in said fluid chamber and for engagement with said fluid actuating means and slidable movement to compress the fluid in said fluid chamber and thereby effect actuation of the control means from said one position to another.

2. A diaphragm pump comprising

(*a*) at least one diaphragm pumping means including a diaphragm housing and a diaphragm secured at its periphery to said housing and deformable in said diaphragm housing to effect displacement of fluid in the latter,

(*b*) supply means communicating with the interior of said housing for conducting fluid to be pumped to said housing,

(*c*) discharge means communicating with the interior of said housing for conducting pumped fluid from said housing,

(*d*) a fluid actuated means supported for reciprocative movement and connected to said diaphragm to deform the latter in said diaphragm housing,

(*e*) a fluid pump for producing fluid under pressure,

(*f*) passage means for conducting pressurized fluid from said fluid pump to said fluid actuated means,

(*g*) fluid flow control means responsive to fluid pressure for actuation from one position to another and associated with said passage means for controlling flow of pressurized fluid to said fluid actuated means so that the latter reciprocates and causes said diaphragm to be actuated to alternately draw fluid to be pumped into said diaphragm housing and discharge fluid from the diaphragm housing,

(*h*) means forming a fluid chamber,

(*i*) passage means communicating with said fluid chamber and said control means, and

(*j*) piston means disposed for slidable movement in said fluid chamber and for engagement with said fluid actuating means and slidable movement to compress the fluid in said fluid chamber and thereby effect actuation of the control means from said one position to another.

3. A fluid pump having at least one fluid displacement means disposed within a housing to divide the interior of the latter into at least one working chamber which communicates with a source of fluid to be pumped to receive such fluid therein and with a point of use of pumped fluid to pass pumped fluid therefrom, in combination with a fluid actuating means comprising,

(*a*) means forming a piston chamber disposed adjacent said housing,

(*b*) a piston disposed for reciprocation within said piston chamber and connected to said fluid displacement means,

(c) a fluid pump for providing a fluid under pressure,
(d) conduit means communicating with said fluid pump to receive pressurized fluid and with the piston chamber to conduct pressurized fluid to the opposite end portions of said piston chamber,
(e) control means responsive to fluid pressure for actuation from one position to another and associated with said conduit means for providing alternate flow of pressurized fluid to the opposite end portions of the piston chamber to cause reciprocation of said piston and thereby actuation of the fluid displacement means and the pumping of fluid to be pumped,
(f) means defining a fluid chamber adjacent each opposite end portion of the piston chamber,
(g) passage means communicating each of said fluid chambers with said control means, and
(h) a plunger means disposed in each of said fluid chambers for slidable movement therein and engageable by said piston adjacent the end of the piston's path of reciprocation to be slid and to compress fluid in said chamber and thereby effect actuation of said control means from said one position to another.

4. A fluid pump having at least one diaphragm disposed within a housing to divide the interior of the latter into at least one working chamber which communicates with a source of fluid to be pumped to receive such fluid therein and with a point of use of pumped fluid to pass pumped fluid therefrom upon actuation of the diaphragm in combination with a fluid actuating means comprising,
(a) a fluid motor disposed adjacent the diaphragm housing and having a piston constructed and arranged for reciprocation connected to said diaphragm,
(b) a fluid pump for providing fluid under pressure,
(c) supply conduit means communicating the fluid pump with said fluid motor to conduct pressurized fluid to the latter on opposite sides of said piston,
(d) return conduit means communicating the fluid pump with said fluid motor on opposite sides of said piston to return spent pressurized fluid to said fluid pump,
(e) control means responsive to fluid pressure for actuation from one position to another and associated with said supply conduit means and said return conduit means to control flow of fluid through the supply and return conduit means to effect reciprocation of said piston and thereby actuation of the diaphragm to cause fluid to be pumped to be drawn into said diaphragm housing and such fluid to be discharged therefrom to the point of use,
(f) means defining a fluid chamber in said fluid motor at opposite ends of the path of reciprocation of said piston,
(g) passage means for communicating each of said fluid chambers with said control means and said fluid chamber, and
(h) a plunger means disposed in each of said fluid chambers for slidable movement therein and engageable by said piston near the end of the piston's path of reciprocation to be slid and to compress fluid in said chamber and thereby effect actuation of said control means from said one position to another.

5. The combination as defined in claim 4 wherein a safety device is provided between said supply and return conduit means to provide for by-passing pressurized fluid around said fluid motor when the pressurized fluid attains a predetermined excess pressure.

6. A fluid actuating means of the character described for a diaphragm pump having at least one diaphragm comprising
(a) means defining a piston chamber disposed adjacent said diaphragm pump,
(b) a piston disposed for reciprocation in said piston chamber and having a piston rod connected to the diaphragm of said diaphragm pump,
(c) a closed cycle fluid pump for pressurizing fluid and having a fluid inlet and outlet,
(d) drive means connected to said fluid pump to drive the latter,
(e) conduit means communicating the fluid outlet of said fluid pump with the opposite ends of the piston chamber to deliver pressurized fluid to the latter,
(f) said conduit means including return conduit means communicating the opposite ends of the piston chamber with the inlet of said fluid pump to conduct spent pressurized fluid from the piston chamber to the inlet of the fluid pump,
(g) control valve means responsive to pressurized fluid for actuation from one position to another disposed in said conduit means for providing alternate flow of fluid to the opposite ends of said piston chamber through said conduit means and alternate flow of fluid from the opposite ends of said piston chamber through said conduit means to thereby effect reciprocation of the piston and actuation of the diaphragm to pump fluid,
(h) means defining a fluid chamber adjacent each opposite end portion of said piston chamber,
(i) passage means communicating each of said fluid chambers with said control means, and
(j) a plunger means disposed in each of said fluid chambers for slidable movement therein and engageable by said piston adjacent the end of the piston's path of reciprocation to be slid and to compress fluid in said chamber and thereby effect actuation of said control valve means from said one position to another.

7. A fluid actuating means of the character described for a diaphragm pump having at least one diaphragm comprising
(a) housing means defining a piston chamber disposed adjacent the diaphragm pump,
(b) a piston disposed for reciprocation in said piston chamber and having a connecting rod connected to the diaphragm pump to effect actuation of the diaphragm upon reciprocation of the piston,
(c) a hydraulic pump for pressurizing a liquid,
(d) drive means connected to said hydraulic pump,
(e) conduit means communicating the hydraulic pump with the opposite ends of the piston chamber to conduct pressurized liquid to the latter,
(f) return conduit means communicating the hydraulic pump with the opposite ends of the piston chamber to conduct spent pressurized liquid from the latter to the hydraulic pump,
(g) a control valve disposed to control flow of liquid through said conduit means and return conduit means to provide in one position flow of pressurized fluid from the hydraulic pump, through the conduit means to one end of the piston chamber and permit spent pressurized liquid to flow from the other end of the piston chamber through the return conduit means, to the hydraulic pump, and in another position provide flow of pressurized liquid and spent pressurized liquid to and from the piston chamber opposite from the said one position so as to cause reciprocation of the piston and actuation of the diaphragm of the diaphragm pump,
(h) said control valve having hydraulic actuated means for effecting movement of the control valve from one position to another,
(i) a hydraulic piston disposed in opposite ends of said piston chamber for slidable movement,
(j) said hydraulic piston being disposed to be engaged by said piston at the latter part of the stroke of said piston and moved to compress a liquid, and
(k) passageway means for each of said pistons for conveying said compressed liquid to the hydraulic responsive means of the control valve to effect actuation of the latter from one position to the other.

8. A fluid pump comprising
(*a*) a pair of diaphragm pump sub-assemblies,
(*b*) each diaphragm pump sub-assembly comprising,
(1) a housing,
(2) a diaphragm disposed within said housing to divide the interior of said housing into at least one working chamber,
(3) supply means communicating with the working chamber for passing fluid to be pumped therein,
(4) discharge means communicating with the working chamber to pass fluid out of the working chamber upon movement of said diaphragm in the working chamber,
(*c*) means forming a piston chamber disposed between said diaphragm pump sub-assemblies,
(*d*) a piston disposed for reciprocation within said piston chamber and connected to the diaphragms of each of the diaphragm pump sub-assemblies,
(*e*) a fluid pump for providing a fluid under pressure,
(*f*) conduit means communicating with said fluid pump to receive pressurized fluid and with the piston chamber to conduct pressurized fluid to the opposite end portions of said piston chamber,
(*g*) exhaust means communicating with the opposite end portions of the piston chamber to permit flow of spent pressurized fluid from the piston chamber,
(*h*) control means responsive to pressurized fluid for actuation from one position to another and associated with said conduit means and said exhaust means for providing alternate flow of pressurized fluid to the opposite end portions of the piston chamber and alternate flow of spent pressurized fluid from the opposite end portions of the piston chamber to cause reciprocation of the piston and thereby actuation of each of the diaphragms of the diaphragm pump sub-assemblies and the pumping of fluid,
(*i*) means forming a fluid chamber adjacent each end portion of said piston chamber,
(*j*) a piston means disposed in each of said fluid chambers for slidable movement therein and engageable by said piston near the latter part of the piston stroke to compress the fluid therein, and
(*k*) passage means communicating each of said fluid chambers with the control means to pass compressed fluid to the latter and thereby effect actuation of the control means from said one position to another.

9. The apparatus of claim 8 wherein a safety device is cooperatively associated with the conduit means to cause pressurized fluid to by-pass said piston chamber in response to a predetermined excess pressure of said pressurized fluid in said conduit means.

10. A fluid pump having at least one diaphragm disposed within a housing to divide the interior of the latter into at least one working chamber which communicates with a source of fluid to be pumped to receive such fluid therein and with a point of use of pumped fluid to pass pumped fluid therefrom in combination with a fluid actuating means comprising

(*a*) means forming a piston chamber disposed adjacent said housing,
(*b*) a piston disposed for reciprocation within said piston chamber and connected to said diaphragm to effect actuation of the latter,
(*c*) fluid supply means for providing fluid under pressure,
(*d*) conduit means communicating with said fluid supply means to receive pressurized fluid and with the piston chamber to conduct pressurized fluid to opposite end portions of the piston chamber,
(*e*) control means responsive to fluid pressure for actuation from one position to another and associated with said conduit means for providing alternate flow of pressurized fluid to the opposite end portions of the piston chamber to cause reciprocation of said piston and thereby actuation of the diaphragm and the pumping of fluid to be pumped,
(*f*) wall means disposed at opposite ends of said piston chamber having a bore therein,
(*g*) a plunger slidably disposed in each of said bore and defining with said bore a fluid chamber,
(*h*) each of said plungers being disposed to be engaged by said piston during the latter part of the stroke of said piston to be slid in said bore and thereby to compress the fluid within said fluid chamber, and
(*i*) passage means communicating at one end with said fluid chamber and at the opposite end with said control means to transmit pressurized fluid to the latter so as to cause the control means to be actuated from said one position to another.

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LAURENCE V. EFNER, *Primary Examiner.*

JOSEPH H. BRANSON, JR., *Examiner.*