

Aug. 13, 1946.

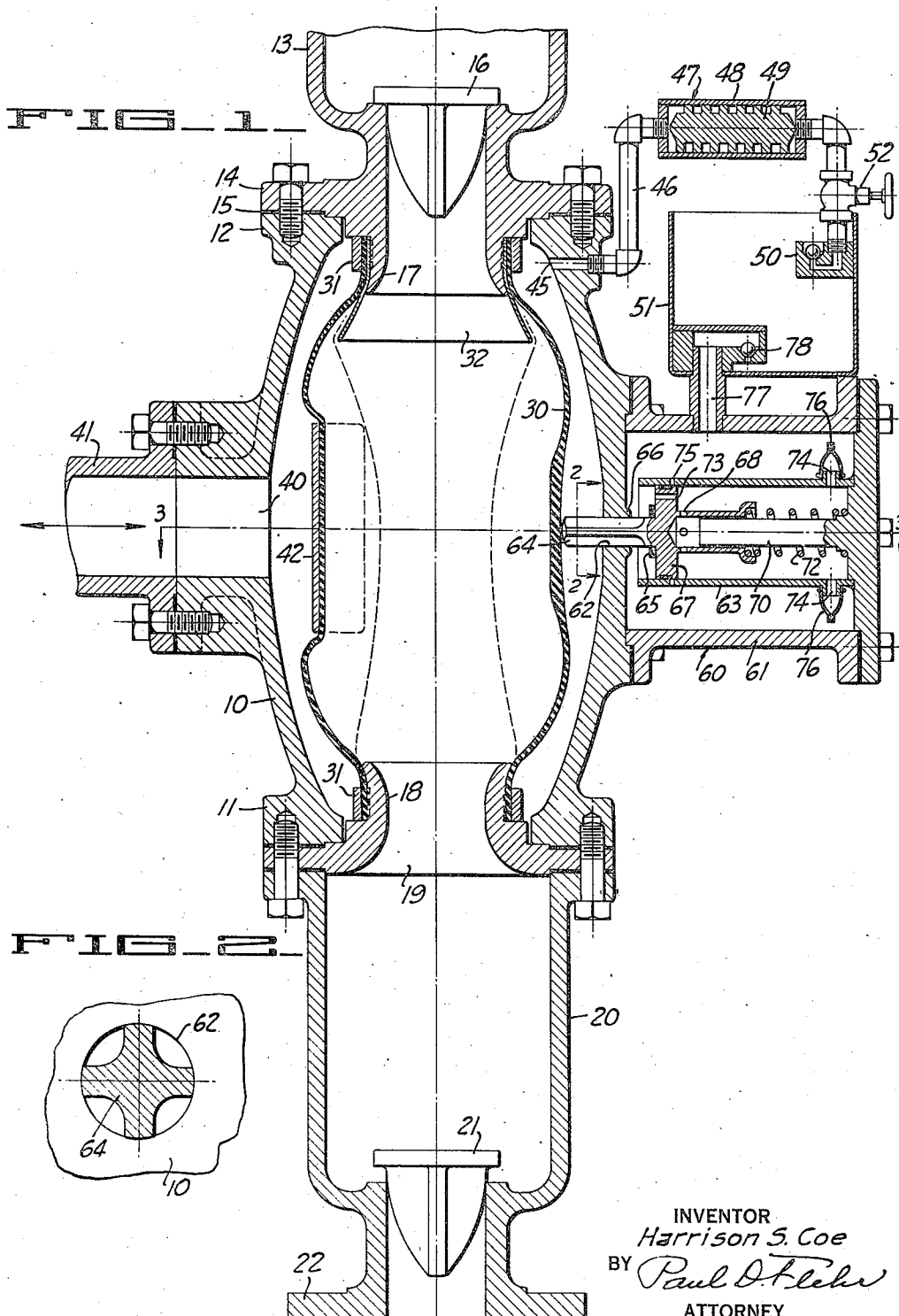
H. S. COE

2,405,734

PUMPING APPARATUS

Filed Aug. 19, 1944

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 3

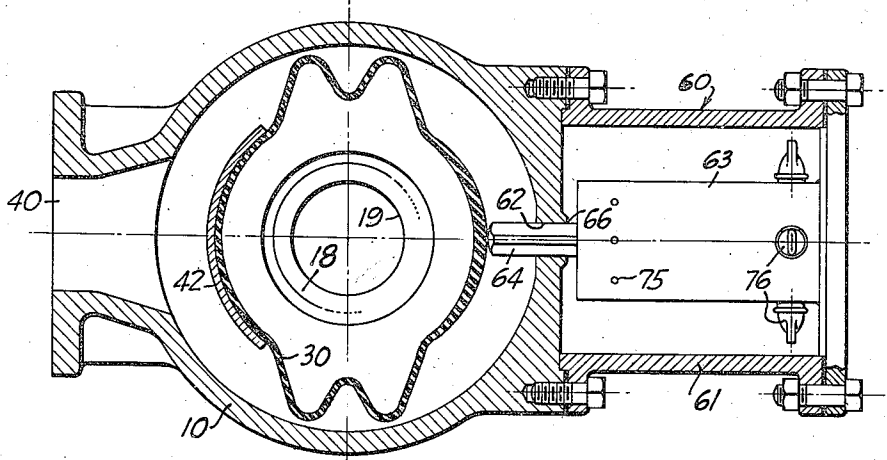
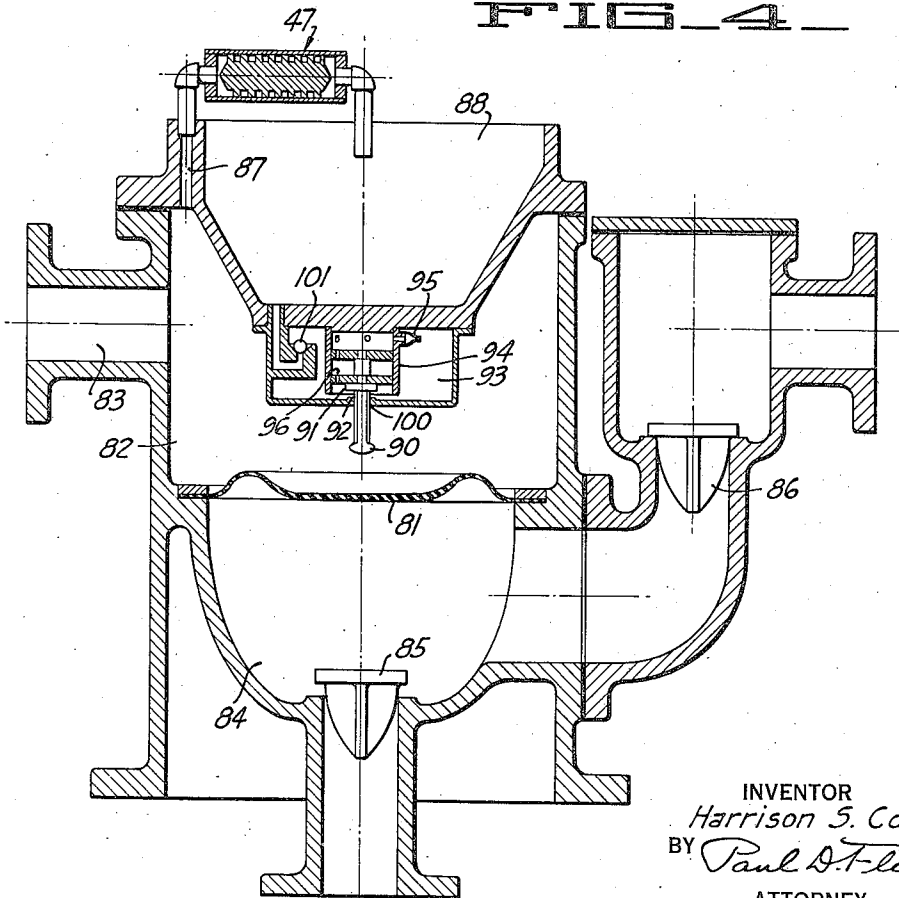


FIG. 4



INVENTOR
Harrison S. Coe
BY *Paul D. Flehr*
ATTORNEY

UNITED STATES PATENT OFFICE

2,405,734

PUMPING APPARATUS

Harrison S. Coe, Palo Alto, Calif.

Application August 19, 1944, Serial No. 550,240

14 Claims. (Cl. 103-44)

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This invention relates to a pumping apparatus of the type in which an impelling liquid body which is actuated by a piston in a cylinder acts against a diaphragm, causing it to pulsate in alternate suction and pressure strokes and thereby to admit and expel the liquid being pumped from a pumping compartment formed at least in part by said diaphragm. The diaphragm in this type of pump serves principally to separate the liquid being pumped from the impelling liquid and prevent the former from contacting the piston and cylinder and cause undue wear or corrosion where abrasive or corrosive fluids are being pumped.

To obtain efficient operation in a pump of this type, the diaphragm must pulsate freely, or without undue strain, in its expansion and contraction of the pumping compartment. Since, for like positions of the piston in the cylinder, the degree of expansion or contraction of the pumping compartment depends entirely upon the volume of impelling liquid in the pump, it will be obvious that the free movement of the diaphragm, throughout a stroke of the piston, can only be maintained if the impelling liquid remains constant within narrow limits.

While this class of pump has marked advantages over ordinary piston pumps where abrasive or corrosive liquids are to be handled and is used under some especially severe conditions in the pumping of mud in drilling of oil wells and like services, its application, up to the present, has been very restricted, because of leakage of fluid past the piston that actuates the impelling liquid. This leakage is never completely avoidable and has made it necessary to stop the pump at intervals, dependent upon the rate of leakage, and adjust the volume of impelling liquid and displace any accumulated air in the impelling liquid compartment. Another factor tending to limit the application of the type of pump under consideration has been the deleterious effect on the apparatus and its operation produced by the overheating of the impelling liquid due to its friction in the pump.

Another factor which has heretofore presented difficulty in this type of pump arises from the tendency of solids and air, separating from the material being pumped, to accumulate in parts of the pumping compartment and interfere with efficient operation.

It is an object of the present invention to provide means to maintain the diaphragm in position to pulsate freely and without strain.

It is a further object of the present invention

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to provide means to prevent air from accumulating in the impelling liquid compartment and to replace liquid escaping therefrom.

It is a further object of the present invention to provide means to introduce liquid into the impelling liquid compartment and to expel liquid therefrom and thereby remove heat generated therein.

Other objects and advantages will appear from the following specification and drawings in which:

Figure 1 is a side view, in cross-section, of a diaphragm pump incorporating the preferred embodiment of my invention.

Figure 2 is a cross-sectional detail taken along the line 2-2 of Figure 1.

Figure 3 is a cross-sectional view taken along the line 3-3 of Figure 1.

Figure 4 is a modification of the invention illustrated in Figure 1 in which a different type of diaphragm is used.

As shown in Figure 1 there is provided a chamber 10 of oblong oval form, which is provided with annular flanges 11 and 12 at its upper and lower ends. Mounted above chamber 10 is a suitable outlet valve body 13 which is secured thereto by suitable bolts through cooperating flanges 12 and 14. An airtight and liquid-proof seal between these members is obtained by the use of a suitable gasket 15. Mounted within valve body 13 I have provided a poppet type valve 16 adapted to move longitudinally and to be operated by differential pressure thereon. Valve 16 is normally maintained in the position shown in Figure 1 by gravity. When the pressure in body 13 below valve 16 sufficiently exceeds the pressure in the area above the valve, the same is opened. When the pressure in body 13 below valve 16 is less than the pressure in the area above the valve, the same maintains the position shown in Figure 1. Valve body 13 extends downwardly into chamber 10 forming a cylindrical projection 17, the use of which will hereafter be explained.

Secured to the lower end of chamber 10 and projecting inwardly thereto I have provided a cylindrical member 18 provided with orifice 19. Also secured to the lower end of chamber 10 by suitable bolts and gaskets, is a valve body 20 and its cooperating poppet valve 21 of the same type as valve 16 and likewise operated by differential pressures within body 20. The entire device is suitably connected to a source of material to be pumped as by means of flange 22.

Within chamber 10 I have provided a diaphragm or tube 30 made of flexible material such

as natural or synthetic rubber, which is secured at its ends to members 17 and 18 respectively by any suitable means to provide a liquid-proof seal. As shown in Figure 1, diaphragm 30 may be secured to members 17 and 18 by clamps 31. Extending downwardly from member 17 within tube 30, I have provided an annular guard tube 32 to prevent the collapse of tube 30 into valve body 13.

Chamber 10 is provided with a cylindrical outlet 40 which is in communication with cylinder 41. Within cylinder 41 there is a reciprocating piston or plunger (not shown) adapted to reciprocate longitudinally therein as indicated by the arrow. On that portion of diaphragm 30 opposite orifice 40 I have provided a metal plate 42 which is adapted to act as a shield against the direct impact on diaphragm 30 of liquid entering chamber 10 through orifice 40 during the pressure stroke of the piston and to prevent diaphragm 30 from being drawn unduly toward or into orifice 40 during the suction stroke of the piston. Diaphragm 30 is preferably fluted as shown in Figure 3 in order that the same may be expanded and contracted with the minimum of "stretching."

As will hereinafter more fully be explained the space within chamber 10 and outside of diaphragm 30 is termed an impelling liquid compartment, and the same is filled with liquid hereinafter called impelling liquid. Upon reciprocation of the piston within cylinder 41 a portion of the impelling liquid is alternately drawn into and out of the cylinder 41 thereby creating alternate suction and pressure pulsations within chamber 10. Alternate suction and pressure within chamber 10 expands and contracts the area within diaphragm 30, known as the pumping or impelled liquid compartment thereby increasing or decreasing the pressure and volume within the same. As will be obvious to those skilled in the art, compression of tubular diaphragm 30 causes the impelled liquid therein to be forced through conduit 13 past valve 16. Expansion of tubular diaphragm 30 creates differential pressure within the same and draws liquid into the same through valve 21.

As has previously been pointed out, on suction strokes of the piston within cylinder 41 a small amount of air may be drawn into the impelling liquid compartment and ultimately this air seeks the highest point therein. To provide an escape for this air I have provided an orifice 45 connected by suitable piping 46 to a resistance means 47 consisting of cylinder 48 within which I have mounted a screw member 49. Passage of liquid through orifice 45 is retarded thereby. Ball-check valve 50 within liquid holding chamber 51 prevents the sucking of liquid into the impelling liquid compartment on the suction stroke. A suitable valve 52 is provided in the event it is found desirable to adjust or close the escape system. As will be pointed out hereinafter, at times it may be desirable to vent a portion of the impelling liquid from chamber 10, and in that event baffle 47 and check valve 50 would operate in the same manner as with the escape of air. I contemplate that liquid chamber 51 may at times function as a heat exchange unit to supply cool liquid to the impelling liquid compartment.

To permit the introduction of liquid into the impelling liquid compartment surrounding diaphragm 30, I have provided a novel valve means designated generally at 60. Valve means 60 consists generally of a cylindrical housing or intermediate compartment 61 which is in communication with the impelling liquid compartment by

means of circular orifice or passage 62. Valve means 60 is suitably secured to chamber 10 to insure a liquid and air-proof seal therewith. Co-axially mounted within housing 61 I have provided a cylindrical member 63. Extending into the impelling liquid compartment through orifice 62 I have provided a push rod 64 adapted to operate valve member 65, which cooperates with valve seat 66. Valve 65 is mounted adjacent one side of a piston 67 which is slidably mounted within cylindrical member 63. Valve 65 is adapted to close against seat 66, and when in engagement therewith prevents communication between housing 61 and chamber 10. In order to maintain push rod 64 accurately aligned within orifice 62 to prevent jamming of the same, I have provided an axially aligned member 70 adapted to cooperate with a cylindrical extension 71 upon piston 67. Spring 72 is adapted to urge piston 67 and valve 65 into closed position, that is, against valve seat 66. The interior of cylinder 63 is in communication with the space surrounding cylinder 63 by restricted orifice 73 in piston 67 and by orifices 74 and 75 in cylindrical member 63. Orifices 74 are provided with closure members 76 of the "pinched tube" type which permit expulsion of liquid from within the cylinder 63 through orifices 74 but do not permit return of liquid into said cylinder through said orifices. Orifices 73 and 75 are simple openings permitting inflow and outflow therethrough. It is obvious therefore that liquid may be expelled from within cylinder 63 much more rapidly than it may enter. Orifices 68 are provided in cylindrical extension 71 to permit the entry of liquid therein and prevent creation of a vacuum. Housing 61 is also in communication with a source of liquid supply 51 through passage 77 and check valve 78. Check valve 78 permits the flow of liquid from chamber 51 into housing 61 through passage 77 but prevents the expulsion of liquid from housing 61 through passage 77 into liquid chamber 51.

Operation of the device and method may briefly be described as follows: A quantity of impelling liquid is placed in the pump sufficient to establish pumping operation. The pump is attached to a source of material to be pumped by suitable connection to flange 22 on valve body 20. A quantity of impelling liquid is placed in liquid supply chamber 51, and valve 52 is opened. Reciprocation of the piston within cylinder 41 as has previously been explained, draws a portion of the impelling liquid within the impelling liquid compartment into cylinder 41 causing expansion of tubular diaphragm 30 creating a differential pressure therein and drawing liquid into the pumping compartment through valve 21. A pressure stroke of the impelling fluid contracts diaphragm 30 and expels liquid from the pumping compartment outwardly through valve 16.

Air entering the impelling liquid compartment would be trapped in chamber 10 at its highest point and would cause the difficulties previously enumerated. Air would tend to be expelled upon a pressure stroke through orifice 45 and resistance means 47 into liquid chamber 51. As a matter of fact, under some conditions, air and liquid or liquid would be expelled through orifice 46 to liquid chamber 51. The flow through orifice 45 may be controlled by resistance 47 and valve 52 as desired.

In the event liquid within the impelling liquid compartment escapes through orifice 46 or around the piston within cylinder 41, it is ob-

vious that tubular diaphragm 30 will expand and will strike push rod 64 and urge valve 65 away from its seat 66, thereby permitting communication between housing 61 and chamber 10, through orifice 62. When valve 65 is forced away from its seat 66, piston 67 is moved into cylinder 63, forcing liquid outwardly therefrom through orifices 73 and 74. When, upon the following pressure stroke, tubular diaphragm 30 is contracted, it is no longer in contact with push rod 64, and spring 72 urges valve 65 toward closed position. Valve 65 is prevented from closing rapidly by virtue of the fact that the sole route by which liquid can reenter cylinder 63 is through metering orifice 73 in piston 67 and orifices 75. Orifices 75 will be closed by piston 67 until valve 65 is nearly closed. When piston 67 opens orifices 75, they will permit a substantial increase in the flow of liquid into cylinder 63 and allow spring 72 to accelerate the closure of valve 65. However, flow of liquid from the impelling liquid compartment into housing 61 through orifice 62 upon the pressure stroke is prevented by check valve 78. Therefore upon a pressure stroke no liquid or pressure in chamber 10 is lost by virtue of the opening of valve 65. However upon the start of the following suction stroke, liquid is drawn from liquid chamber 51 through conduit 77 into housing 61 and from there, through orifice 62, into the impelling liquid compartment within chamber 10.

If liquid drawn in during the period when valve 65 is open balances the liquid being lost from the impelling liquid compartment, the operation is in equilibrium and the position of the diaphragm at the end of the succeeding suction stroke remains stabilized. If valve 65 closes too quickly to admit liquid to balance this loss the diaphragm 30 expands and increases the range of movement of piston 67 thereby causing the period during which valve 65 remains open to be extended and in turn causing more liquid to be drawn in through valve 78. This progressive expansion of diaphragm 30 will cease when the liquid drawn in balances the liquid loss. In rare cases liquid may enter through valve 78 during the period when valve 67 is open as diaphragm 30 approaches the end of the suction stroke. Under most conditions pressure exists in the impelling liquid compartment during this period and all passage of liquid through orifice 62 will occur following the succeeding pressure stroke.

In the modification of my invention illustrated in Figure 4, the tubular diaphragm 30 of Figure 1 is replaced by a simple flexible sheet-like diaphragm 81. Impelling liquid compartment 82 is suitably connected to a reciprocating piston arrangement, not shown, by conduit 83. Operation of the impelling liquid within compartment 82 operates diaphragm 81 in much the same manner as the operation of diaphragm 30 as has heretofore been explained. Pulsation of diaphragm 81 creates alternate pressure and suction within impelled liquid or pumping compartment 84 thereby causing the entry of material through poppet valve 85 upon a suction stroke and expulsion of material through poppet valve 86 upon a pressure stroke. Escape of air or liquid through orifice 87 and into liquid chamber 88 is identical to the escape of the same through orifice 45 as pointed out in connection with Figure 1.

However the device permitting the introduction of compensating liquid to the impelling liquid in compartment 82 from liquid chamber 75

88 is slightly different in the modification shown in Figure 4 than as shown in Figure 1. Upward movement of diaphragm 81 upon a suction stroke causes diaphragm 81 to strike push rod 90 and raise valve 91 from its seat 92 thereby permitting communication between impelling fluid compartment 82 and valve chamber 93. Upward movement of valve 91 causes expulsion of liquid above double piston arrangement 94 through the rubber nipples 95 as previously explained in connection with the operation of valve means 60 in Figure 1. However the return of valve 91 to its closed position is solely by gravity. Reinroduction of liquid into the area above the dual piston arrangement 94 is through orifices 96 therein. The dual piston arrangement is to insure perfect alignment of push rod 90 in the orifice 100 in chamber 93. When impelling fluid compartment 82 and chamber 93 are in communication, expulsion of liquid therefrom upon the pressure stroke is prevented by the operation of ball-check valve 101. However under conditions of suction, introduction of liquid from liquid chamber 88 into liquid chamber 82 through valve 91 is permitted.

The cycle of operation and introduction of liquid into the impelling liquid compartment is the same as has been previously explained in connection with Figure 1.

I claim:

1. In a pump having a chamber and a diaphragm within said chamber and dividing the same into an impelling liquid compartment and a pumping compartment, inlet and outlet valves permitting the inflow and outflow of liquid from said pumping compartment upon movement of said diaphragm, a liquid holding chamber, valve means adapted to function in response to the action of the diaphragm to allow or prevent communication between said impelling liquid compartment and said liquid holding chamber, said valve means including means adapted to retard the closure of the valve through an interval of time dependent in duration on the volume of liquid in the impelling liquid compartment.

2. In a diaphragm pump wherein the diaphragm is adapted to move in response to the action of impelling liquid in contact therewith, a chamber adapted to act as a source of impelling liquid but spaced from the impelling liquid in contact with said diaphragm, a valve responsive to the position of said diaphragm to permit or prevent communication between said chamber and said impelling liquid in contact with said diaphragm, and means adapted to retard the closure of said valve through an interval of time dependent upon the position of the diaphragm at the conclusion of its suction stroke.

3. In a diaphragm pump wherein a diaphragm dividing an enclosed space into a pumping compartment and an impelling liquid compartment is adapted to move in response to the action of impelling liquid in said impelling liquid compartment; a chamber adapted to act as a source of impelling liquid and spaced from the impelling liquid compartment, valve means responsive to the position of said diaphragm and adapted to open and close a passage between said chamber and said impelling liquid compartment, and means adapted to retard the closure of said passage through an interval of time dependent on the position of the diaphragm at the conclusion of its suction stroke.

4. In a diaphragm pump wherein a diaphragm dividing an enclosed space into a pumping com-

partment and an impelling liquid compartment is adapted to move in response to the action of impelling liquid in said impelling liquid-compartment; a chamber adapted to act as an intermediate source of impelling liquid, a passage leading from said chamber to an exterior source of supply of impelling liquid, a valve adapted to close said passage under the influence of pressure in said chamber and to open said passage under the influence of suction therein, a passage communicating said chamber with said impelling liquid compartment, and means responsive to the position of said diaphragm adapted to open and close said passage.

5. In a diaphragm pump wherein a diaphragm dividing an enclosed space into a pumping compartment and an impelling liquid compartment is adapted to move in response to the action of impelling liquid in said impelling liquid compartment, a chamber adapted to act as an intermediate source of impelling liquid, a passage leading from said chamber to an exterior source of supply of impelling liquid, a valve adapted to close said passage under the influence of pressure in said chamber and to open it under the influence of suction therein, a passage communicating said chamber with said impelling liquid compartment, valve means responsive to the position of said diaphragm and adapted to open and close said passage, said valve means including a cylinder enclosed at one end, a piston in said cylinder, means adapted to cause a movement of said piston in said cylinder in response to an action of the diaphragm, means adapted to establish a force against said piston in the opposite direction to said movement, a valve adapted to maintain a position in controlled relation to the position of said piston and to close said passage between said chamber and said impelling liquid compartment in response to movement of said piston under the influence of said force, and means adapted to control the movement of the piston due to said force including an orifice adapted to admit liquid into said cylinder.

6. In a diaphragm pump wherein the diaphragm is adapted to move in response to the action of impelling liquid in contact therewith, a chamber adapted to act as a source of impelling liquid and spaced from the impelling liquid in contact with said diaphragm, valve means responsive to the position of said diaphragm to permit communication between said chamber and the impelling liquid in contact with said diaphragm, whereby the opening of said valve is controlled by the movement of said diaphragm and the closure of said valve is controlled by the metering of liquid into a fluid chamber associated with said valve means.

7. In a pump, a compartment, a tubular diaphragm adapted to be mounted in said compartment and to divide the same into an inside pumping compartment and an outside impelling liquid compartment, an auxiliary supply chamber, valve means adapted to permit or prevent the flow of liquid from said auxiliary chamber to said impelling liquid compartment and from said impelling liquid compartment to said supply chamber, the opening of said valve means being controlled by the position of said diaphragm at the end of its suction stroke and closure of said valve means being controlled by metering of liquid into a fluid chamber associated with said valve means.

8. In a diaphragm pump wherein a diaphragm dividing an enclosed space into a pumping compartment and an impelling liquid compartment is

adapted to move in response to the action of the impelling liquid in said impelling liquid compartment, a chamber adapted to act as intermediate source of impelling liquid, a passage leading from said chamber to an exterior source of supply of impelling liquid, a valve adapted to close said passage under the influence of pressure in said chamber and to open it under the influence of suction therein, a second passage communicating said chamber with said impelling liquid compartment, valve means responsive to the position of said diaphragm and adapted to open and close said second passage comprising a compartment of variable space, a member adapted to contract said space in response to an action of the diaphragm, means adapted to exert a force against said member tending to expand said space, a valve adapted to maintain a controlled position in relation to the position of said member and to open said passage on the contraction of said space and to close it on the expansion of said space, and means adapted to control the rate of expansion of said space.

9. A diaphragm pump embracing an enclosed space divided by a diaphragm into a pumping compartment and an impelling liquid compartment, an intermediate compartment separating the impelling liquid compartment from a source of liquid supply, a passage leading from said source into said intermediate compartment, a valve in said passage adapted to admit liquid into and to close against the flow of liquid out of said compartment, a passage leading from said intermediate compartment into said impelling liquid compartment, a valve adapted to open and close said passage, means adapted to open said valve in response to an action of the diaphragm, and means adapted to close said valve.

10. A diaphragm pump embracing an enclosed space divided by a diaphragm into a pumping compartment and an impelling liquid compartment, an intermediate compartment separating the impelling liquid compartment from a source of liquid supply, a passage leading from said source into said intermediate compartment, a valve in said passage adapted to admit liquid into and to close against the flow of liquid out of said compartment, a passage leading from said intermediate compartment into said impelling liquid compartment, a valve adapted to open and close said passage, means adapted to open said valve in response to an action of the diaphragm, means adapted to close said valve, and means adapted to retard the closure of said valve, said means including a chamber, a passage communicating said chamber with a body of liquid in the pump and means adapted to vary the volume of the space enclosed in said chamber in response to an action of the diaphragm.

11. A diaphragm pump embracing an enclosed space divided by a diaphragm into a pumping compartment and an impelling liquid compartment, a passage leading from said impelling liquid compartment to a point exterior to the pump and adapted for the expulsion of fluid from the pump, an intermediate compartment separating the impelling liquid compartment from a source of liquid supply, a passage leading from said source into said intermediate compartment, a valve in said passage adapted to admit liquid into and to close against the flow of liquid out of said compartment, a passage leading from said intermediate compartment into said impelling liquid compartment, a valve adapted to open and close said passage, means adapted to open said valve in response

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to an action of the diaphragm, and means adapted to close said valve.

12. A diaphragm pump embracing an enclosed space divided by a diaphragm into a pumping compartment and an impelling liquid compartment, a passage leading from said impelling liquid compartment to a point exterior to the pump and adapted for the expulsion of fluid from the pump, an intermediate compartment separating the impelling liquid compartment from a source of liquid supply, a passage leading from said source into said intermediate compartment, a valve in said passage adapted to admit liquid into and to close against the flow of liquid out of said compartment, a passage leading from said intermediate compartment into said impelling liquid compartment, a valve adapted to open and close said passage, means adapted to open said valve in response to an action of the diaphragm, means adapted to close said valve, and means adapted to retard the closure of said valve, said means including a chamber, a passage communicating said chamber with a body of liquid in the pump and means adapted to vary the volume of the space enclosed in said chamber in response to an action of the diaphragm.

13. In a pump characterized by a chamber and a diaphragm dividing said chamber into an im-

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PELLING liquid compartment and a pumping compartment, said diaphragm being adapted to pulsate in response to a reciprocating movement of liquid in said impelling liquid compartment and to cause successive periods of change in the volume of said pumping compartment; means adapted to admit liquid into said impelling liquid compartment, means adapted to function in response to an action of the diaphragm and to cause said first named means to admit said liquid, and means adapted to control the volume of liquid admitted by said first named means, said means being adapted to function in accordance with the position occupied by the diaphragm at the termination of a period of change in the volume of the pumping compartment.

14. In a diaphragm pump incorporating a pumping chamber, an impelling liquid chamber, and a diaphragm forming a dividing wall between said chambers, an intermediate chamber between the impelling liquid chamber and a source of liquid supply, and means adapted to operate in response to the action of the diaphragm and to cause the transfer of liquid from the intermediate chamber into the impelling liquid chamber and from the source of supply into the intermediate chamber.

HARRISON S. COE.