

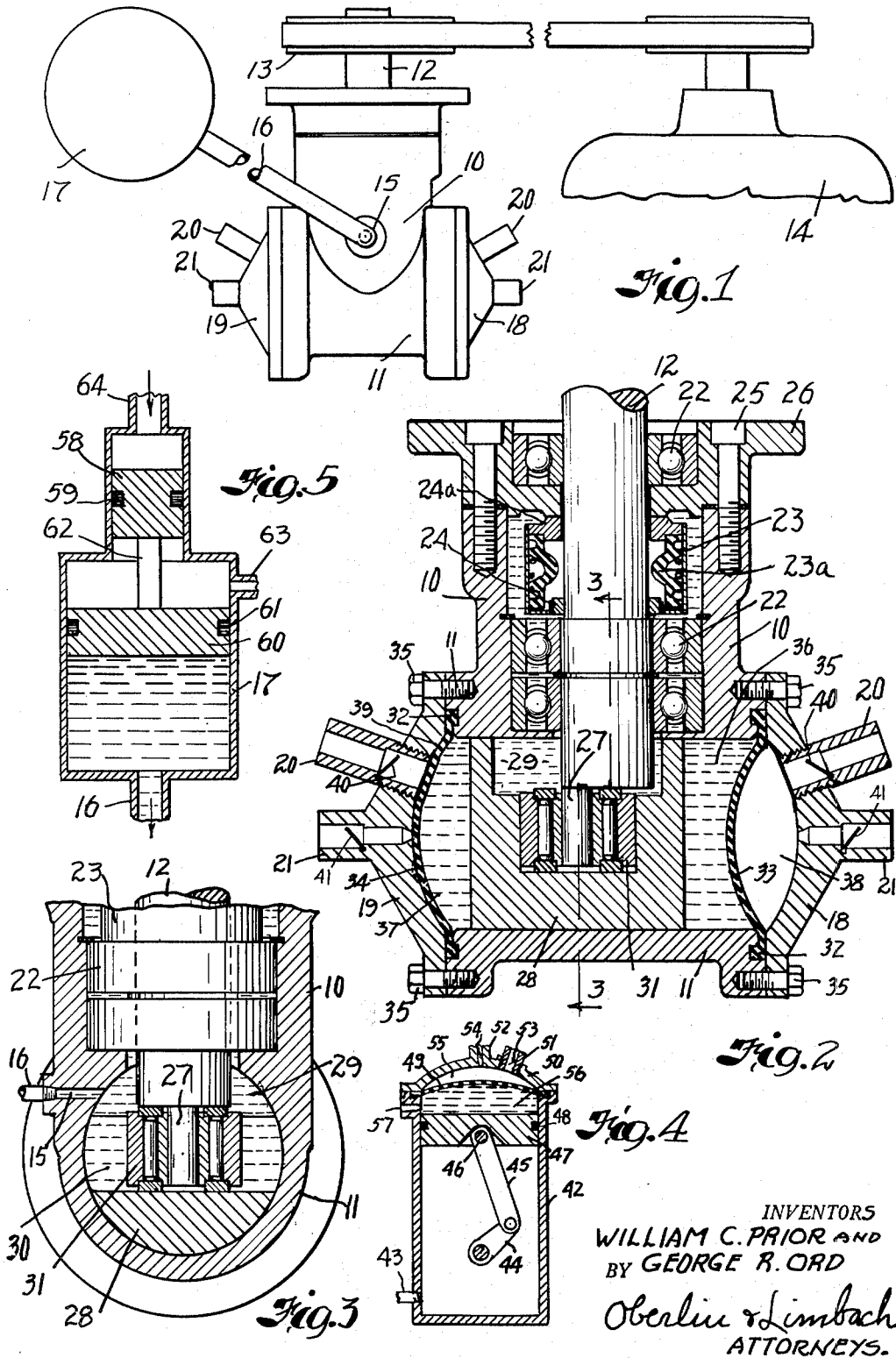
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HYDRAULICALLY ACTUATED DIAPHRAGM PUMP

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HYDRAULICALLY ACTUATED DIAPHRAGM PUMP

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This invention relates, as indicated, to hydraulically actuated diaphragm pumps and more specifically to new and novel features in the construction of such pumps whereby their pressure output can be increased and accurately controlled, while permitting the pumps to be operated at very high speeds. At the outset of this description it should be understood that the classification of our invention as a pump is intended to include the uses of our invention as a liquid displacing device, a gas compressing device, and a device for metering such fluids.

In order that hydraulically actuated diaphragm pumps may be operated efficiently, especially when used to compress gases to high pressure, it is necessary that a definite quantity of fluid be contained between the diaphragm of the pump and the piston which actuates that diaphragm. In other words, the fluid piston of a diaphragm pump must have a carefully regulated volume if the pump is to operate efficiently. When a diaphragm pump is operated, the volume of its fluid piston will change for two reasons.

As the pump warms up during its initial period of use an unbalance often results between the volume of the fluid piston and the volume of the chamber which receives the fluid piston. This unbalance is caused by the difference between the coefficients of thermal expansion of the materials comprising the body of the pump and the fluid comprising the fluid piston. Usually the volume of the fluid piston will be too great.

Since the pump contains internal moving parts, the pump casing, by necessity, must contain some opening through which some driving means extends. Though this opening will contain some sealing device, small quantities of fluid will escape therethrough thus reducing the volume of the fluid piston. This is especially the case when the pump is used to deliver fluids at very high pressures.

Whenever the volume of the fluid piston is too great, the pump will attempt to force it into a volume insufficient to accommodate it, thereby rendering the pump inoperable or even seriously damaging it. Whenever the volume of the fluid piston is too small, while the pump is being used to compress a gas, some gas will remain in the compression chamber of the pump after each stroke. This remaining gas will be recompressed on subsequent strokes so that the pump is operated inefficiently. When the pump is used to deliver a gas at a very high pressure, the remaining space in the compression chamber due to fluid leakage may be great enough that all the gas in the compression chamber may be compressed on every stroke of the pump without being driven from the pump. If this should be the case, the pump would continue to operate without delivering any gas at all.

It is therefore the principal object of this invention to provide a high outlet pressure diaphragm pump.

It is a further object of this invention to provide a diaphragm pump of the fluid piston type wherein changes

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in the volume of the fluid piston may be automatically compensated.

Other and more particular objects of the invention will appear as the description proceeds.

To the accomplishment of the foregoing and related ends, the invention, then comprises the features herein-after fully described and particularly pointed out in the claims, the following description and the annexed drawing setting forth in detail one illustrative embodiment of the invention, this being indicative, however, of but one of the various ways in which the principles of the invention may be employed.

In said annexed drawings:

Fig. 1 is a schematic diagram of a diaphragm pump construction in accordance with our invention shown in conjunction with its associated equipment;

Fig. 2 illustrates a longitudinal sectional view of a preferred construction for our invention;

Fig. 3 illustrates a vertical sectional view taken along the lines 3-3 in Fig. 2;

Fig. 4 illustrates a cross-sectional view of one construction for a single chamber diaphragm pump which employs the principles of our invention; and

Fig. 5 is a cross-sectional view of the preferred construction for the fluid reservoir of our invention.

Broadly stated, our invention comprises a fluid pump, in combination: a first chamber, a second chamber, a flexible diaphragm forming a common wall between said first and second chambers, a liquid filling said second chamber, means associated with said second chamber for displacing the liquid therein to cyclically move said diaphragm from a neutral position to cyclically increase and decrease the capacity of said first chamber, a reservoir maintaining a body of liquid under adjustably constant pressure, and means providing a communicating passage between said reservoir and said second chamber, said passage provided with a net effective cross-sectional area which will permit, at the pressure at which the liquid in said second chamber is displaced, a maximum rate of liquid flow therethrough, which is substantially less than the rate at which the volume of said first chamber is changed during said cyclic movement of said diaphragm.

With reference now to Fig. 1, the pump constructed in accordance with our invention is indicated generally as a solid casing made up of two perpendicular intersecting cylinders 10 and 11. Protruding axially from the cylinder 10 is a drive shaft 12 which, through a pulley 13, is adapted to be rotated by any suitable driving means generally indicated at 14. From an orifice 15, shown more clearly in Fig. 3, in the periphery of the cylinder 10, a conduit 16 protrudes which at its other end is connected to a suitable fluid reservoir 17. Mounted on the ends of the cylinder 11 are two heads 18 and 19 which contain intake conduits 20 and exhaust conduits 21. When the pump is used, the exhaust conduits 21 are connected to any suitable storage tank or piece of pressure-operated equipment. When the pump is used to compress a fluid other than air, the intake conduits 20 are connected to any suitable source of said fluid. It should here be noted that while the intake lines 20 may be connected to the same source of supply, they may also be connected to different sources of supply whereby the two ends of the cylinder 11 may be used as two independent pumps. This procedure would be very advantageous where it was desired to compress two different fluids to the same pressure and at the same rate.

Referring to Figs. 2 and 3 where sectional views of this equipment are shown, the drive shaft 12 is rotatably mounted along the axis of the cylinder 10 by means of suitable bearings 22. Mounted around the shaft 12 and

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rotatable with it is a conventional mechanical seal arrangement which includes a metal shell 23, a spring loaded rubber sleeve 23a contained therein, a rubber O-ring 24, and a carbon ring 24a. Solidly mounted on the cylinder 10 by means of bolts 25 is a cap 26 in which is centrally located an opening through which the shaft 12 protrudes. As the cap 26 is tightened down by the bolts 25, it contacts the carbon ring 24a which in turn compresses the sleeve 23a. The sleeve 23a maintains the shell 23 against the ring 24 and the ring 24a against the cap 26. The surface between the ring 24a and the cap 26 is lapped so that the seal arrangement can rotate with the shaft 11, while sealing the opening in the cap 26. Mounted on the shaft 12 and integral with it is an axially extending eccentric pin 27.

Slidably mounted in the cylinder 11 is a cylindrical piston 28 which contains a peripheral cavity 29 adapted to receive the end of the drive shaft 12. The cavity 29 is connected to the reservoir 17 by the conduit 16 and the port 15 in the cylinder 10. Extending into the piston 28 from the cavity 29 is a cavity 30, extending perpendicular to the axes of the piston 28 and the cylinder 10, which contains a slidable set of bearings 31. The bearings 31 are adapted to receive the eccentric pin 27. Covering the ends of the cylinder 11 and fitting into grooves 32 therein are flexible diaphragms 33 and 34. As the heads 18 and 19 are tightened onto the cylinder 11 by means of bolts 35 the edges of the diaphragms 33 and 34 are compressed effecting a fluid seal between the heads 18 and 19 and the cylinder 11. The bodies of incompressible fluid contained in the cavities 36 and 37 between the piston 28 and the diaphragms 33 and 34 are referred to as fluid pistons. The cavities 38 and 39 between the heads 18 and 19 and the diaphragms 33 and 34 are referred to as the compression chambers of the pump. The conduits 20 in the heads 18 and 19 contain inwardly opening check valves 40 and the conduits 21 in the heads 18 and 19 contain outwardly opening check valves 41.

When a pump of the type herein described is used to compress a gas, the conduits 20 are connected to any suitable reservoir of that gas and the conduits 21 are connected to a storage tank or a piece of gas-operated equipment. The shaft 12 is then rotated by the driving means 14, thereby causing the eccentric pin 27 to reciprocate the piston 28 in the cylinder 11. As the piston 28 is moved toward the head 18 and away from the head 19, the fluid piston 36 forces the diaphragm 33 into the compression chamber 38. When the gas pressure in the compression chamber 38 exceeds the gas pressure in the conduit 21, the check valve 41 therein will open, and further movement of the piston 28 toward the head 18 will cause the fluid piston to evacuate the compression chamber 38. As the piston 28 is being moved toward the head 18, it is moving away from the head 19, whereby the fluid piston 37 and hence the diaphragm 34 are drawn away from the head 19 so that the compression chamber 29 is enlarged. As soon as the pressure in the compressor chamber 39 falls below the pressure in the exhaust conduit 21, the check valve 41 therein will close, and the rarefaction of the gas in the chamber 39 caused by the further movement of the piston 28 away from the head 19 will cause the check valve 40 to open. Gas will then flow into the compression chamber 39 until the piston 28 is again driven toward the head 19. Thus as the shaft 12 is rotated reciprocating the piston 28, compressed gas is delivered alternately through the conduits 21 in the heads 18 and 19.

With reference now to Fig. 4 wherein is shown a cross-section of a one-chamber pump constructed in accordance with our invention, 42 designates the casing of the pump which contains in its lower end a vent 43. Journalled in the casing 42 is a drive shaft 44 to which is pivotally connected a connecting rod 45. The connecting rod 45 is in turn connected through a suitable wrist pin 46 to a

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piston 47. In an annular groove in the piston 47 is a packing disc 48 frictionally sealing the clearance passage between the piston 47 and the casing 42. Covering the top of the casing 42 and fitting into an annular groove therein is a flexible diaphragm 49. Solidly mounted on top of the casing 12 and held rigidly thereagainst is a cap 50 which contains an inlet conduit 51 and an exhaust conduit 52. The conduit 51 contains an inwardly opening check valve 53, and the conduits 52 contain an outwardly opening check valve 54. The cavity 55 between the head 50 and the diaphragm 49 is referred to as the compression chamber of the pump, and the body of fluid 56 contained between the diaphragm 49 and the piston 47 is referred to as the fluid piston. A conduit 57 in the casing 42 is connected to the fluid piston 56 through one or more very small orifices in the casing 42. In practice, these orifices may be provided by sealing in the conduit 57 a block of porous metal.

When this pump is used to compress a gas the inlet conduit 51 is connected to any suitable source of that gas; the exhaust conduit 52 is connected to any suitable storage tank or piece of gas-operated equipment; the conduit 57 is connected to the fluid reservoir 17. The crank shaft 44 is then rotated by any suitable driving means so that the piston 47 is reciprocated in the casing 42. As the piston 42 and hence the fluid piston 56 and the diaphragm 49 are moved away from the head 50, the check valve 53 in the conduit 51 opens and the compression chamber 55 is filled with gas. When the piston is then moved toward the head 50, the check valve 53 closes and the gas is compressed in the compression chamber 55 until the pressure in the chamber 55 reaches the pressure of the gas in the conduit 52, at which point the check valve 54 will open. Further movement of the piston 47 toward the head 50 then drives the compressed gas from the chamber 55 into the conduit 52.

With reference to Fig. 5 wherein the preferred construction for the fluid reservoir of our invention is shown, 17 designates the casing of the reservoir, which is constructed of two coaxial cylinders. Slidably mounted in the larger cylinder is a piston 60 which contains in a peripheral annular groove a packing disc 61. Rigidly connecting the piston 58 to the piston 60 is a rod 62. The casing 17 contains a conduit 63 venting the space between the pistons 58 and 60. A conduit 16 extends from the reservoir on the side of the piston 60 remote from the piston 58, and conduit 64 extends from the reservoir on the side of the piston 58 remote from the piston 60. The conduit 16 and the volume of the reservoir on the side of the piston 60 remote from the piston 58, are filled with an incompressible fluid. In practice the conduit 64 is connected to the outlet conduit, 21 in Figs. 1 and 2 and 51 in Fig. 4, of the pump, and the conduit 16 is connected to the fluid piston of the pump through a very restricted passageway. In Fig. 2, this restricted passageway is the clearance between the piston 28 and the walls of the cylinder 11. In Fig. 4, this restricted passageway comprises the pores in the block of metal sealed in the conduit 57. This reservoir maintains a proportion between the pressure in the pump delivery conduit and the pilot pressure applied to the fluid in the reservoir. This proportion, as described in relation to the apparatus in Fig. 5, is the inverse proportion between the area of the piston 58 and the area of the piston 60.

In the preferred construction of our invention, as described in Fig. 2 and Fig. 3, the entire interior of the pump, with the exclusion of the compression chambers 38 and 39 and the interior of the seal arrangement on the shaft 12, is filled with a hydraulic fluid as is the conduit 16 to the reservoir 17.

When the pumps comprehended by our invention are operated, changes in the volumes of fluid pistons are automatically compensated for by applying a liquid pressure to the fluid piston through a passage which has an

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effective cross-sectional area which will permit, at the pressure at which the fluid in the fluid pistons is displaced, a maximum rate of liquid flow therethrough which is substantially smaller than the rate at which the volume of the compression chamber is changed during the cyclic movement of the diaphragm of the pump. This fluid pressure is applied to a reservoir as described above which is connected to the fluid piston through a very restricted passageway. This passageway must permit fluid flow therethrough, but this fluid flow must be small enough that the volume of the fluid piston will not be decreased during a compression stroke to the point where the pump uselessly compresses gas in the compression chamber of the pump without displacing it from the pump. Furthermore, the passageway must be small enough that it doesn't permit enough fluid flow therethrough that the fluid piston on an intake stroke would become large enough that an insufficient amount of gas would be drawn into the compression chamber.

The pressure applied and the size of the restricted passage are such that during normal operation the volume of the fluid flowing into the reservoir on the compression stroke will just equal the volume of the fluid flowing from the reservoir during the remainder of the pump cycle.

Whenever an imbalance results from expansion of the fluid piston, the pressure applied to the fluid piston as it contacts the head of the pump on the compression stroke will cause an increased rate of fluid flow into the reservoir, and this increased rate of flow into the reservoir will not be offset by an increased rate flow from the reservoir during the remainder of the pump cycle. Therefore, whenever the volume of the fluid piston becomes too great, more fluid will be passed into the reservoir than from it, thereby reducing the volume of the fluid piston to normal.

Whenever an imbalance results from fluid seepage from the pump whereby the volume of the fluid piston is too small, the pressure on the fluid piston during the compression stroke will not build up to the delivery pressure as rapidly as it would for normal volume of the fluid piston, and if the volume of the fluid piston is far enough below normal, the pressure on the fluid piston will not build up to the delivery pressure at all. Because of this reduced rate of pressure build-up, the amount of fluid delivered to the reservoir on each stroke is reduced, but the amount of fluid driven from the reservoir remains constant. Thus, when the volume of the fluid piston falls below normal, more fluid will be driven from the reservoir than is returned to it so that the volume of the fluid piston will be increased.

It can then be seen that the fluid pressure applied to the fluid piston through the restricted passageway will compensate for any changes in the volume of the fluid piston.

In operation, the pressure applied to the reservoir must be somewhere between the inlet and delivery pressures of the pump, and as the delivery pressure is increased, so must the pressure applied to the reservoir be increased. Experiment and analysis have corroborated the fact that the maximum pressure at which the pump will deliver a gas is substantially a linear function of the pressure that is applied to the reservoir. Thus, the utilization of the particular reservoir pressure system herein illustrated is very advantageous because the pilot pressure maintained on the fluid in the reservoir is proportional at all times to the pressure in the delivery conduit of the pump. Because of this fact, the maximum pressure capability of the pump is always increasing. As the pressure builds up in the gas storage tank and the pump delivery conduit, so does the pressure in the fluid reservoir build up, thus enabling the pump to increase the pressure in the storage tank still further. Whenever a pump of a fixed maximum pressure output is desired, the fluid reservoir herein described could be replaced by a reservoir on which a fixed pilot pressure is main-

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tained, or by a reservoir on which is maintained a pressure which is inversely proportional to the pressure in the pump delivery conduit.

Our invention provides a much sought solution to the problem of the provision of a diaphragm pump which can efficiently be used for a high pressure and high output gas compressor. By variation of the pilot pressure applied to the fluid reservoir associated with our pump, it is possible to adapt the pump so that it will deliver a gas at a given maximum pressure. By the use of a fluid reservoir as shown in Fig. 5, a gas compressor is provided which will deliver gas at an ever-increasing maximum pressure. Furthermore pumps constructed in accordance with our invention have eliminated the problem of using sluggish check valves in the fluid compensating system and hence may be operated much faster. Because the entire interior of our pump is flooded with hydraulic fluid, very effective lubrication of all moving parts is afforded so that the life of the pump is extended. A further prominent advantage of the preferred construction of the pump of our invention is its simplicity and light weight, only five pounds.

Although our invention is herein described in accord with its use as a high pressure gas compressor, it may be utilized as a fluid metering device for delivering regulated quantities of gases or liquids.

Other modes of applying the principle of the invention may be employed, change being made as regards the details described, provided the features stated in any of the following claims or the equivalent of such be employed.

We therefore, particularly point out and distinctly claim as our invention:

1. In a fluid pump, in combination: a first chamber having inlet and outlet passageways, a second chamber, a flexible diaphragm forming a common wall between said first and second chambers, a liquid filling said second chamber, means associated with said second chamber for displacing the liquid therein to cyclically move said diaphragm from a neutral position to cyclically increase and decrease the capacity of said first chamber, a reservoir maintaining a body of liquid under pressure, and means providing a continuously open communicating passage between said reservoir and said second chamber, said passage provided with a net effective cross-sectional area which is smaller than the net effective cross-sectional area of said outlet passageway to permit, at the pressure at which the liquid in said second chamber is displaced, a maximum rate of liquid flow therethrough, which is substantially less than the average rate at which the volume of said first chamber is changed during said cyclic movement of said diaphragm.

2. In a fluid pump, in combination: a first chamber having inlet and outlet passageways, a second chamber, a flexible diaphragm forming a common wall between said first and second chambers, a liquid filling said second chamber, means associated with said second chamber for displacing the liquid therein to cyclically move said diaphragm from a neutral position to cyclically increase and decrease the capacity of said first chamber, a reservoir maintaining a body of liquid under a pressure which is between the maximum and minimum pressures in said second chamber during one cycle of said piston's movement, and means providing a continuously open communicating passage between said reservoir and said second chamber, said passage provided with a net effective cross-sectional area which is smaller than the net effective cross-sectional area of said outlet passageway to permit at the pressure at which the liquid in said second chamber is displaced, a maximum rate of liquid flow therethrough, which is substantially less than the average rate at which the volume of said first chamber is changed during said cyclic movement of said diaphragm.

3. In a fluid pump, in combination: a first chamber having inlet and outlet passageways, a second chamber,

a flexible diaphragm forming a common wall between said first and second chambers, a liquid filling said second chamber, means associated with said second chamber for displacing the liquid therein to cyclically move said diaphragm from a neutral position to cyclically increase and decrease the capacity of said first chamber, a reservoir maintaining a body of liquid under a pressure which is proportional to the pressure in said delivery conduit, and means providing a continuously open communicating passage between said reservoir and said second chamber, said passage provided with a net effective cross-sectional area which is smaller than the net effective cross-sectional area of said outlet passageway to permit, at the pressure at which the liquid in said second chamber is displaced, a maximum rate of liquid flow therethrough, which is substantially less than the average rate at which the volume of said first chamber is changed during said cyclic movement of said diaphragm.

4. The apparatus described in claim 3 characterized further in that said means associated with said second chamber for displacing the liquid therein comprises a piston reciprocable in said second chamber and said means providing a communicating passage between said reservoir and said second chamber comprising the clearance between the periphery of said piston and the wall of said second chamber.

5. The apparatus described in claim 3 characterized further in that said reservoir comprises first and second housings mounted in fixed spaced relation with respect to each other, first and second pistons reciprocable respectively in said first and second housings, said pistons rigidly held in fixed spaced relation with respect to each other, a body of liquid impounded in said second housing on the side of said second piston remote from said first piston, and communicating means between said outlet passageway and the interior of said first housing on the side of said first piston remote from said second piston.

6. In a fluid pump, in combination: a first chamber having inlet and outlet passageways, a second chamber, a flexible diaphragm forming a common wall between said first and second chambers, a liquid filling said second chamber, means associated with said second chamber for displacing the liquid therein to cyclically increase and decrease the capacity of said first chamber, a reservoir maintaining a body of liquid under a pressure which is greater than the pressure in said inlet passageway, and means providing a continuously open communicating passage between said reservoir and said second chamber, said passage provided with a net effective cross-sectional area which is smaller than the net effective cross-sectional area of said outlet passageway to permit, at the pressure at which the liquid in said second chamber is displaced, a maximum rate of liquid flow therethrough, which is substantially less than the average rate at which the volume of said first chamber is changed during said cyclic movement of said diaphragm.

7. In a fluid pump, in combination: first and second chambers each having inlet and outlet passageways; third

and fourth chambers; flexible diaphragms respectively comprising common walls between said first and third and between second and fourth chambers; a liquid filling said third and fourth chambers; means associated with said third and fourth chambers for displacing the liquid therein to cyclically move said diaphragms from neutral positions to cyclically increase and decrease the capacities of said first and second chambers; a reservoir maintaining a body of liquid under pressure; and means providing continuously open communicating passages between said reservoir and said third and fourth chambers, said passages provided with net effective cross-sectional areas which are smaller than the net effective cross-sectional areas respectively of the outlet passageways leading from said first and second chambers to permit, at the pressure at which said liquid in said third and fourth chambers is displaced, a maximum rate of liquid flow therethrough which is substantially less than the average rates at which the volumes of said first and second chambers are changed during said cyclic movements of said diaphragms.

8. A pump comprising first and second chambers, each having inlet and outlet passageways; third and fourth chambers; flexible diaphragms respectively comprising common walls between said first and third and between said second and fourth chambers; a liquid filling said third and fourth chambers; means associated with said third and fourth chambers for displacing the liquid therein to cyclically move said diaphragms from their neutral positions to cyclically increase and decrease the capacities of said first and second chambers; at least one small continuously open orifice in a wall of each of said third and fourth chambers, said orifices having net effective cross-sectional areas which are smaller respectively than the net effective cross-sectional areas of the outlet passageways leading from said first and second chambers; and means for maintaining, at the sides of said orifices remote from said third and fourth chambers, a fluid pressure which is between the pressure in said inlet passageways and the pressure in said outlet passageways.

9. A pump comprising first and second chambers, each having inlet and outlet passageways; third and fourth chambers; flexible diaphragms respectively comprising common walls between said first and third and between said second and fourth chambers; a liquid filling said third and fourth chambers; a piston alternatively reciprocable into and out of said third and fourth chambers; and means for maintaining along a peripheral portion of said piston intermediate of its ends a fluid pressure which is proportional to the pressure in said delivery conduits.

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