Aug. 31, 1954

E. E. THEIS

DIAPHRAGM PUMP

2,687,696

Filed Feb. 8, 1951

2 Sheets-Sheet 1

Fig. 1.

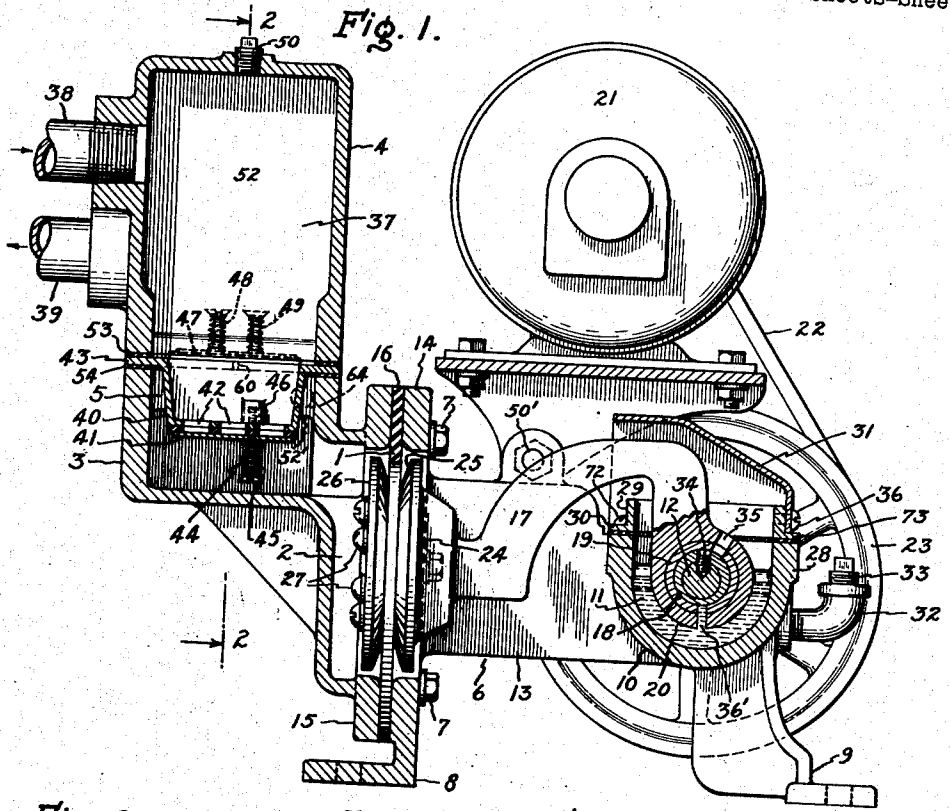


Fig. 2.

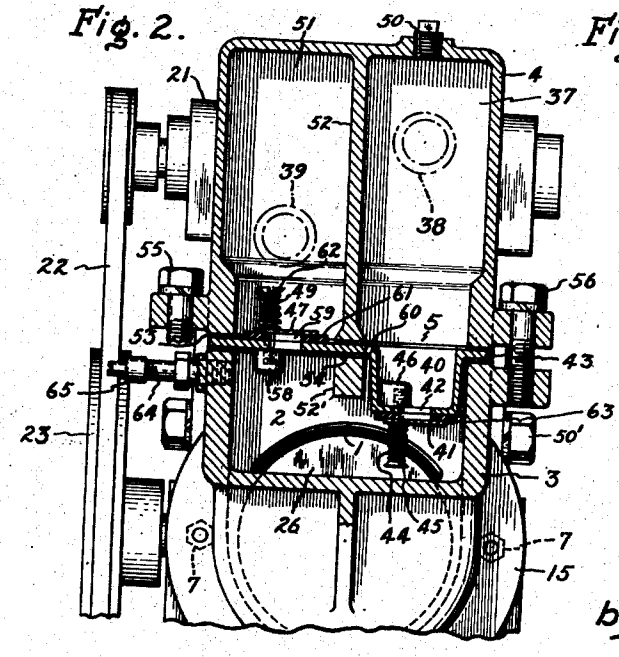


Fig. 3.

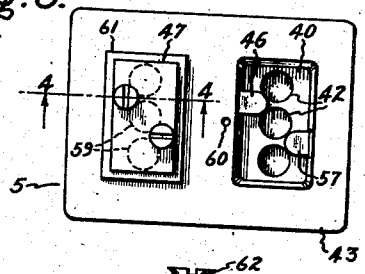
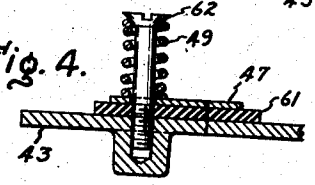


Fig. 4.



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2 Sheets-Sheet 2

Fig. 5.

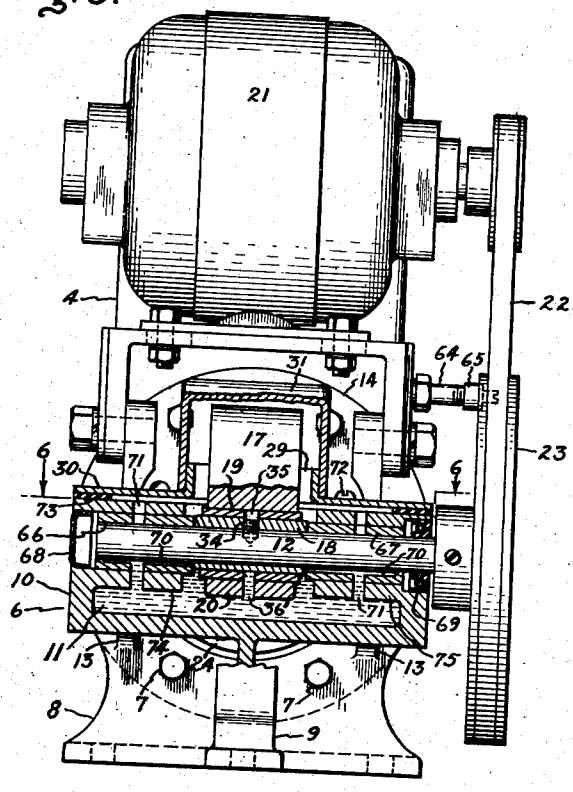
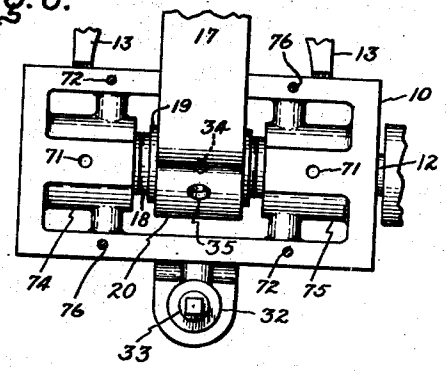


Fig. 6.



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UNITED STATES PATENT OFFICE

2,687,696

DIAPHRAGM PUMP

Elmer E. Theis, Jacksonville, Fla.

Application February 8, 1951, Serial No. 209,930

13 Claims. (Cl. 103—150)

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My invention relates to positive displacement pumps and parts thereof, and particularly concerns diaphragm pumps.

A general object of my invention is to provide an improved diaphragm pump, and, more specifically, to improve the reliability and operating efficiency of diaphragm pumps.

A specific object of my invention is to provide an improved diaphragm pump of the type having a vertically disposed diaphragm, to minimize lubrication difficulties in such pumps, and to provide self-priming characteristics and improved valve operation thereof.

It is a further specific object to provide a self-priming diaphragm pump wherein the diaphragm is not subjected to the pressure of the outlet conduit when the pump is idle.

Another object is to provide a flap of flutter valve construction, particularly adapted for use in positive displacement pumps, which is inexpensive, readily fabricated, rugged and wear resistant, and which acts rapidly and positively.

A further specific object of my invention is to provide a diaphragm pump in which the load imposed on the driving mechanism is maintained approximately constant through a wide range of differential pressures across the pump.

An additional object is to minimize, in a liquid pump, erratic operation and wearing effects due to sand or other foreign matter in the liquid.

The specific embodiment of my invention described herein, and shown in the accompanying drawings, comprises a diaphragm pump particularly adapted for pumping water from a shallow well and for similar purposes, but it will be apparent that several features of my invention are adapted to other apparatus and other uses. These novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which Fig. 1 is a partially sectionalized side elevation of a pump in accord with my invention; Fig. 2 is a sectional view taken along the line 2—2 of Fig. 1; Fig. 3 is a top view of the inlet and outlet valve assembly for the pump of Figs. 1 and 2; Fig. 4 is a detail side view of a portion of the valve assembly of Fig. 3; Fig. 5 is a right hand end view of the pump of Fig. 1 with several of the parts broken away more clearly to disclose portions of the drive arrangement; and Fig. 6 is a top view of a part of the drive arrangement taken on line 6—6 of Fig. 5 and comprising members shown in the right hand portion of Fig. 1.

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Referring now to the drawings, Fig. 1 discloses a pump comprising a diaphragm 1 operating in, and forming the movable wall of, a displacement or pump chamber 2 in a casting 3. An inlet, vacuum, or suction chamber and an outlet, discharge, or compression chamber are provided in a casting 4, and this casting is attached to the casting 3 with the inlet and outlet chambers separated from the pump chamber by a valve assembly 5. A third major casting 6 is attached to the pump chamber casting 3 by means of bolts 7, and comprises mounting legs 8 and 9 to support the whole pump assembly, a trough or basin 10 partially filled with a quantity of oil 11, and bearings for a main drive shaft 12. Arms 13 connect the trough to an annular flange portion 14, and the flange portion is bolted by bolts 7 to the flange 15 of the pump chamber casting 3 to clamp the peripheral portion 16 of the circular diaphragm between the flanges. A yoke or connecting rod 17 is arranged to drive the diaphragm in and out of pump chamber 2 through the operation of a journal 18 having an eccentric bore which is carried on the shaft 12 and rotates with the shaft in a bearing 19 in boss 20 of the connecting rod 17. Shaft 12 is rotated by a suitable motor 21, which, through belt 22, drives a pulley 23 mounted on the end of shaft 12.

Diaphragm 1 may be a flat sheet or disc of rubber, synthetic rubber, leather, or other suitable material, and it completely closes the circular opening in the right hand side of the casting 3, being there held in place between the flanges 14 and 15 by means of the bolts 7. These bolts pass through suitable openings in the flange 14 and in the peripheral portion 16 of the diaphragm, and are threaded into bores in the flange 15.

Connecting rod 17 terminates at the diaphragm in an enlarged plate 24, of which the face 25 in contact with the diaphragm is suitably beveled from a flat central portion in the direction away from the diaphragm with the edges slightly rounded to prevent cutting of the diaphragm. Facing the plate 24 on the other side of the diahpragm is a second substantially similar plate 26 bolted by bolts 27 through the diaphragm to the plate 24. These bolts 27 extend through the flat central portions of the plates, and no leakage through the diaphragm can occur since the diaphragm acts as a gasket

or washer for each of the bolts 27 and the bolt holes in the plates 24 and 26. Starting from the diaphragm, the connecting rod 17 is shaped or formed in an upward direction for most of its length, and terminates in a downward extension which, in part, comprises boss 20. Accordingly, boss 20 may be disposed in the bath of oil 11 in the trough 10 while the connecting rod extends up and over the retaining wall 28 of the trough, and any extension of the wall, such as is provided by the portion 29 of splash cover 30. This splash cover comprises a hoodlike central portion 31 which extends up over a portion of the connecting rod, and over the otherwise exposed portion of the trough, to prevent the oil from splashing out, to prevent foreign matter, such as water or undesired objects, from entering the oil bath, and to prevent accidental contact of external objects or parts of a person with this portion of the connecting rod.

The trough is conveniently filled to a predetermined desired level of the oil bath 11 through a pipe elbow 32 closed by a plug 33. The plug is arranged so that when oil is poured into the elbow to the level of the top thereof, the oil in the trough is brought up to the desired level. This level is preferably at about the center of boss 20, and shaft 12.

Bearing 19 in boss 20 of connecting rod 17 may comprise a bearing insert, as shown, or it may be simply a smooth cylindrical bore extending through the boss 20. This bearing 19 cooperates with the cylindrical surface of journal member 18, through which extends an eccentric cylindrical bore to receive shaft 12. The eccentric journal member is keyed to the shaft by means of a set screw 34 threadably engaging in a threaded hole in the journal member, preferably at the thickest portion thereof. The set screw 34 may either bite into the surface of shaft 12, or it may, as shown in the drawing, extend into a keyway or indentation in shaft 12. Access to the set screw 34 is provided by means of an opening 35 extending through the boss 20 and bearing insert 19, the opening 35 being preferably large enough freely to pass set screw 34. Alternatively, set screw 34 may be sufficiently short to be withdrawable completely into eccentric journal member 18 to clear the shaft 12 at the inner end and the surface of bearing 19 at the outer end. Adjustments to the set screw are made by rotating shaft 12 until the set screw aligns with the opening 35, permitting the insertion of a set screw wrench or screwdriver, as required, through the opening 35. This operation is performed after the removal of the hood portion 31 of splash member 30, the hood being removably attached thereto by bolts 36.

The opening 35 which serves as the set screw access hole further operates to improve the lubrication of the bearing. Oil from the bath 11 is free to enter or leave the bearing through this opening. The most satisfactory lubrication has been found to be obtained when an additional opening 36' is provided through the lower portion of the boss 20 and bearing insert 19. When a lower opening is thus provided, oil is pumped through the bearing from the lower opening out through the upper opening 35. Whether or not opening 36' is provided, however, increased oil flow through the bearing and improved lubrication result from the provision of opening 35.

Casting 4, which comprises an inlet, vacuum or suction chamber 37, and an outlet, discharge or compression chamber not seen in Fig. 1, is provided with an inlet conduit 38 communicating with the suction chamber 37, and an outlet conduit 39 communicating with the compression chamber. The inlet chamber is separated from the pump or displacement chamber 2 by the inlet portion 40 of valve plate 41 covering a plurality of inlet valve ports 42 formed in the metal body member 43 of the valve assembly. The movable valve plate 41 is spring-loaded into the position to seal ports 42 by means of a compression spring 44 surrounding and bearing against the head 45 of a bolt threaded into a boss 46 formed as part of the valve body 43. Two such springs, bolts, and bosses are provided for the inlet valve plate of the assembly 5 and an equal number for the outlet valve plate 47. As shown in Fig. 1, in dotted lines, the outlet valve comprises a valve plate 47, biased toward closing position by compression springs 48 and 49.

It will be understood that valve plate 41 isolates the suction chamber 37 from pump chamber 2 until the pressure in the pump chamber is sufficiently reduced to permit the pressure in chamber 37 to overcome the force of springs 44 and to lift, in the downward direction, plate 41 from its seated position, thereby to partially uncover ports 42. The plate 47, on the other hand, remains seated to isolate the compression chamber from the pump chamber until the pump chamber pressure is sufficient to lift plate 47 upwardly against the biasing force of springs 48 and 49 to uncover the outlet valve ports.

A suitable priming opening to permit the initial filling of chamber 37 and preferably conduit 38 is provided at the top of the suction chamber 37 and may be closed by a plug 50.

The motor 21, as shown in this figure, is mounted on a platform pivotally supported by bolts 50'. Belt tension is readily adjusted by pivoting the motor and motor deck about bolts 50', with the bolts slightly loosened, and thereafter tightening the bolts to hold the motor in its adjusted position. A further understanding of the motor mounting will be had from a later consideration of Fig. 5.

Rotation of shaft 12 and journal 18 in bearing 19 resulting from motor operation causes the boss 20 to travel in a circular path. This motion of the boss is translated into an horizontal rectilinear component at the center of face 25 of plate 24. The whole plate, and with it, plate 26 and the central portion of diaphragm 1, will be driven back and forth, in and out of chamber 2, to increase and decrease the volume and hence the pressure in the chamber. A slight tilting motion is also imparted to the plates but this is of small consequence and may be readily reduced if desired by increasing the distance between shaft 20 and diaphragm 1. The centers of plates 24 and 26 are preferably at approximately the same height above the ground or floor as the center of shaft 20.

The motor 21, in a typical construction, may be rated at one-third horsepower at 1800 revolutions per minute, or a little less, and the ratio of pulley diameters may be such as to drive shaft 20 at a little more than 600 revolutions per minute. The diameter of effective area of the diaphragm 1, which is, of course, the diameter of the opening in chamber 2 covered by the diaphragm, may be about 5 inches, and the diameter of plates 24 and 26, about 4½ inches. The stroke of the diaphragm, taken at the center, may be of the order of one-quarter inch, and in pumping water from a shallow well in which the water level in the

well is about 18 feet below the pump and the water is being pumped against a tank pressure of between 20 and 40 pounds per square inch, a pump with these dimensions constructed in accord with my invention will have a capacity of approximately 6 or 7 gallons per minute.

Referring now to Fig. 2, which is a sectional view taken along line 2—2 of Fig. 1, it will be seen that the suction chamber 37 is separated from compression chamber 51 by a dividing wall 52, and the bottom of each of the side walls of each chamber conforms to a predetermined horizontal plane. A bottom portion 52' of the dividing wall comprises a solid web member formed as a part of casting 3 extending under valve body member 43 and dividing the upper portion of chamber 2 into two compartments. A gasket 53 is arranged against the apertured lower face of the casting 4, and the body member 43 of the valve assembly is disposed against the lower face of the gasket thereby to be sealed against the casting 4. A similar gasket 54 is arranged between the under side of the valve body member 43 and the upper face defined by the top of the walls of the pump chamber casting 3, including the top of the web member 52'. Bolts 55 and 56 in connection with suitable lug extensions serve to hold the castings 3 and 4 tightly together against the valve body member and gaskets. The remaining portions of the pump as seen in Fig. 2, including the positions of the inlet and outlet conduits 38 and 39, indicated in dashed lines, and plug 50, motor 21, belt 22, pulley 23, trough 10, bolts 7, flange 15, diaphragm 1, and plate 26 are each identified in this figure to accord with the above discussion in respect to Fig. 1.

The construction of the valve assembly is most readily understood from a consideration of Fig. 3, a top view of the assembly, and Fig. 4, a sectional detail view of a portion of the assembly taken along line 4—4 of Fig. 3, taken together with the sectional view of Fig. 2.

The valve body member 43 is essentially a flat plate, but it is provided with a cup-shaped inlet portion 40 and with protruding bosses 46 and 57, in the inlet portion, and bosses 58, in the outlet portion, only one of which is shown in the drawings. The body member is provided with three aligned inlet ports 42, three similar aligned outlet ports 59, and an inlet valve bypass conduit 60 in the form of a small opening extending through the body member and arranged to communicate constantly, that is without being closed at any time, between the inlet or suction chamber 37 and the pump chamber 2.

The outlet portion of the valve assembly comprises the movable valve plate 47, which is preferably generally rectangular in shape. This plate seats against a resilient seat member 61, which is preferably made of synthetic rubber, or the like, and which is preferably of the shape of plate 47 but slightly larger in dimensions. The resilient member 61 may be affixed to valve body member 43 by the use of a suitable adhesive, although it has been found that so long as member 61 is not affixed to the movable plate 47 it will remain stationary, whereby only the inertia of plate 47 effects the speed of valve operation. As a result, the valve operates with great rapidity. Ports 59, of course, extend through both the member 43 and the member 61. Bolts 62, as best shown in Fig. 4, extend through the plate 47 with a free or clearance fit and through the resilient seat member 61, and they are threaded into suitable tapped openings in bosses 58 of body member 43. Two such bolts 62 are provided for the plate 47, and the compression springs 48 and 49, as seen in Figs. 1, 2 and 4, bias the plate 47 into the position to cover ports 59. When the pressure in chamber 2 increases sufficiently, plate 47 is lifted away from the surface of seat member 61 to permit the escape of liquid under the plate 47 into outlet or compression chamber 51.

The inlet valve arrangement is similar to that of the outlet valve but is oriented to supply liquid to chamber 2 from the inlet or suction chamber 37. Accordingly, valve plate 41 is seated against resilient member 63, which may be affixed if desired to the underside of the cup-shaped portion 40 of valve body member 43. Ports 42 extend through the body member 43 and through the resilient member 63. Compression spring 44 biases plate 41 into the seated position against the under surface of member 63 to close the inlet valve by covering ports 42. It will be understood that a second spring similar to spring 44 is provided at the diagonal position indicated by boss 57 in Fig. 3 to act in the same manner at this second portion of the plate. The bolt head 45 seen in Figs. 1 and 2 which holds spring 44 against plate 41 is arranged in a position under boss 46, as seen in Fig. 3, and a similar bolt head, not shown, is arranged under boss 57. The bolts for each plate 41 and 47 are threaded into the tapped openings to a depth sufficient to provide the desired proper biasing force against the plates and are individually adjusted to equalize the biasing force of each respective spring of each plate, whereby the plates are lifted directly away from their valve seats by the actuating pressure, and no substantial amount of tilting of the plates occurs.

The bypass conduit or port 60 is seen in Fig. 2 to connect or communicate between inlet chamber 37 and pump chamber 2 and is further seen to be small as compared to the valve ports 42. In practice, the diameter of the conduit 60 may be approximately one thirty-second ($\frac{1}{32}$) of an inch, while the ports 42 are of about one-half inch in diameter. The ratio of the respective cross sectional areas of a valve port and of the bypass port, accordingly, is of the order of 250:1. These dimensions are approximate and are set forth to indicate the orders of magnitude only.

Fig. 2 additionally discloses a "snifter" valve 64 in communication with the chamber 2. As shown, a valve cap 65 closes this valve. In use in a pressure tank water supply system, however, the cap is replaced by a tube connecting the "snifter" valve to a control which admits air into the chamber 2 whenever the water level in the pressure tank of the system rises above a predetermined point. When this occurs, air is admitted to the valve 64 and is sucked into the chamber 2 at each suction stroke of the pump to be pumped into chamber 51 and thence to pass into the pressure tank of the system. Such control of pressure systems is known to those familiar with such systems. The snifter valve itself conveniently comprises a construction substantially identical to the valve commonly employed in automobile inner tubes and comprises a conventional "valve inside" threaded into the tube identified as valve 64.

Fig. 5 is a view of the pump, partially cut away, taken from the end opposite that shown in Fig. 2. In Fig. 5, certain portions of the pump heretofore described have been identified by the reference

numerals corresponding to those used in Figs. 1 through 4, and further description of many of these parts is not required in connection with this figure since the descriptions heretofore given apply in the same manner.

The drive arrangement for connecting rod 17 is clearly shown in Fig. 5 to comprise shaft 12 supported to rotate in bearing inserts 66 and 67, which, in turn, are arranged in suitably bored bosses extending inwardly from the end walls into trough 10. Oil is prevented from leaking along the shaft 12 out of the trough at opposed ends thereof by a sealing plug 68 and by a shaft oil seal 69, respectively, the latter being preferably of the known type making use of a synthetic rubber member surrounding and held in contact with the shaft by means of an annular tension spring. The shaft 12 is lubricated in bearings 66 and 67 by means of grooves or ducts 70 formed on the lower inner surfaces of these bearings, the ducts being below the normal level of the oil 11. The oil so supplied is permitted to drain back into the oil bath through openings 71 bored through the top and bottom portions of bearings or bearing inserts 66 and 67 and through the bosses carrying these bearings. It has been found that the provision of openings 70 helps to retard pump of oil toward the ends of the shaft, thereby to minimize oil leakage through the seals 68 and 69. Housing 30, including the raised central portion 31, prevents contamination of the oil passing through upward openings 71, and prevents any of this oil from splashing out of the trough. The trough cover 30 is held in place by bolts 72, which thread into the trough body, and a gasket 73 is preferably provided under the cover to prevent any leakage out under the edges thereof.

Fig. 6 is a top view taken along the line 6—6 of Fig. 5 and clearly discloses bosses 74 and 75 which, respectively, hold bearing inserts 66 and 67, and which are formed as part of the end walls of the casting comprising the trough.

Openings 71 extend down through the bosses to communicate with the bearing surfaces of shaft 12. Holes 76 extend into the trough body and are internally tapped to receive the cover hold-down bolts. The positions of the set screw access opening 35 and of the set screw 34 are further shown in Fig. 6. It will be noted that the shaft is shown not in the position to provide access to the set screw in this view. Fig. 6 also shows the oil fill opening 32 and plug 33.

Arms 13 are partly shown in each of Figs. 5 and 6, these arms being provided to connect the portion of casting 6 which comprises the oil trough 10 to the portion of this casting which includes the flange 14 for the outer face of the diaphragm, as described in connection with Fig. 1. It will be understood that the motor pivot bolts 59' are threaded into suitable upward extensions of the arms 13 to support the motor mounting platform. This arrangement will be most readily understood by taking Figs. 1 and 5 together.

In typical operation of the pump in a shallow well and pressure tank water supply system, an extension of pipe or conduit 38 may lead down a well into a body of water, of which the level should not be more than about 22 feet below the pump, the conduit terminating below the water level in a foot valve, and an extension of pipe 39 may be connected to a pressure tank which is to be partially filled with water, the remainder of the tank above the water to contain a pocket of air under pressure. The pressure in the tank may be maintained by the pump at from about 20 to about 40 pounds per square inch, and suitable automatic controls are preferably provided to maintain the desired water level, or pressure, or both, in the tank. Such controls may, for example, start the pump motor when the tank pressure drops to a predetermined minimum, such as 20 pounds per square inch, shut off the motor when the pressure reaches a desired maximum, such as 40 pounds per square inch, and may admit air to the displacement chamber through "snifter" valve 64 when the water level exceeds a predetermined height in the tank, whereby the pump will force additional air into the tank.

The pump is prepared for initial operation in such a system by removing priming plug 50 and filling the inlet or suction chamber 37 and conduit 38 with clean water, thereafter replacing the plug. As the pump motor starts operating to drive plates 24 and 26 and diaphragm 1 in and out of chamber 2, it is necessary that the water in chamber 37 be drawn into the pump chamber 2, since the pump chamber would otherwise continue full of air and no valve operation or pump action would occur. As the pump starts operation, it is necessary, if water is to be drawn into the pump or displacement chamber from the suction chamber through the inlet valve, that the pressure in the pump chamber must be reduced below atmospheric pressure by an amount slightly greater than the head of water above the well level plus the spring biasing force against inlet valve plate 41. To fulfill this requirement, the pressure in the pump chamber may have to be reduced, for example, by almost one-half atmosphere. The volumetric change in the pump chamber produced by a stroke of the diaphragm, however, is a small percentage of the total volume.

Accordingly, except for the provision of bypass opening 60, it is probable that pumping would not start. This opening provides an escape for some of the air originally in the pump chamber back into the suction chamber. On a suction stroke, as the pump is started, a very small amount of water is drawn into the pump chamber, although no water may be drawn from the well into conduit 38 through the foot valve, as permitted by expansion of the air trapped in the inlet system, and this will occur even though the amount of such air is very small. The water so sucked in falls to the bottom of the pump chamber, and on the following compression stroke some air is forced upwardly through bypass conduit 66 to bubble up to the top of the suction chamber. At the same time air may or may not be pumped through the outlet valve depending on the back pressure in the outlet system and the spring bias on the outlet valve plate. In either case, the next suction stroke will produce increased suction force, that is, a lower absolute pressure in the pump chamber, which will suck a larger amount of water from the inlet chamber. The increased amount of air in the inlet system assists, of course, in this increase, as does the water in the pump chamber. The next compression stroke forces additional air through conduit 66 further to increase the intake of water into the pump chamber on the succeeding suction stroke. As more and more water enters the pump chamber, the tendency is to pump increasingly great amounts of air into the outlet chamber at each compression stroke, since a greater

air pressure is produced when the pump chamber contains more water.

As the pump chamber fills more and more with water, the absolute pressure in the pump chamber at each suction stroke becomes lower and lower, and when the pump chamber becomes perhaps one-half or two-thirds full of water, the pumping in of water through the well foot valve may start even though the well water level may be 15 feet below the pump. The remaining air in the pump chamber is now rapidly pumped out into the outlet system and the pump is completely in operation.

The conduit **60** further operates automatically to overcome obstacles which would otherwise prevent pumping. For example, if the well level is very low, or if the pressure in the outlet system or the bias on the outlet valve plate is high, or if the foot valve is leaky, a large pocket of air may have formed in the suction chamber by the time the pump chamber is filled with water. In this case, the water level in the suction chamber may drop to the level of conduit **60** but it will not ordinarily drop below. It is believed that the reason is that on suction strokes occurring after the water level reaches the conduit a substantial amount of air is drawn in through the conduit **60** now not covered with water. This air, entering in the form of a jet, mixes with the water in the pump chamber and forms bubbles or pockets of air at the outlet valve ports. On compression strokes some air and water are forced back into the suction chamber through conduit **60** partially replenishing any water that may have been sucked through the inlet valve and the air in the pockets around the outlet valve ports is pumped into the outlet chamber. The net result is to remove at least some air from the suction chamber and to pump this air into the outlet chamber, while retaining in the suction chamber at least enough water to keep the inlet valve plate thoroughly wet and probably enough under most circumstances to keep the cup-shaped portion **40** of valve body **41** substantially filled.

When sufficient air has thus been pumped from the inlet chamber, water will enter from the well through conduit **38** to cover conduit **60**. As the water starts to flow in through conduit **38**, the suction chamber will still contain a large volume of air. As pump operation continues, however, this air mixes with the water entering the pump chamber, and after an extended period of operation, little or no air will remain in the suction chamber.

A further important advantage of the conduit **60** is in removing the starting load on the pump motor and in providing only a relatively small force on the diaphragm during stand-by periods. After a period of pumping, the motor being de-energized, the pressure in the pump chamber is equalized with the suction chamber pressure, disregarding the relatively small head of water in the pump and suction chambers themselves, because of unobstructed conduit **60**. The resultant pressure differential on the opposite faces of the diaphragm is thus equal to the force necessary to maintain the water in conduit **38** above the level in the well, assuming that some leakage may occur through the foot valve. This force is of the order of one-half atmosphere or less and is equal to the difference between the atmospheric pressure on the outer face of the diaphragm and on plate **24**, and the lower pressure of the water in the pump chamber on the other face of the diaphragm and on plate **26**. If the difference in head between the diaphragm and the well water level is 17 feet, the differential pressure will be about 7 pounds per square inch. Of course, if the foot valve does not leak at all, the force may be much less or substantially zero.

Pumps in accord with the invention have demonstrated that starting against a pressure of the order of one-half atmosphere, or less, is a great deal more certain than would be starting, for example, against a storage tank pressure of 20 pounds per square inch. The life of the diaphragm is also increased when it is subjected to the lower differential pressure during stand-by periods. It will be noted that the differential pressure on the diaphragm during stand-by periods as given in the above example is with the assumption that the foot valve at the lower end of the inlet conduit is leaky. As mentioned above, if the foot valve does not leak, the differential pressure on the diaphragm, when conduit **60** is provided as described, will be appreciably less.

It is to be further noted that a small pocket of air in the suction chamber will permit, together with conduit **60**, slow speed operation of the pump with very low load on the motor since water may be slowly forced in and out through conduit **60** to expand and contract the air pocket. Consequently, in my invention, a motor may be employed having a starting torque much lower than that required in pumps so arranged that the first motion of the diaphragm on starting may have to be against the full storage tank pressure.

A still further advantage of conduit **60** lies in its effect in maintaining more constant the load on the pump motor in pumping against varying storage tank pressures. For low tank pressures, very little water is forced back through conduit **60** from the pump chamber into the suction chamber on each pressure stroke, since the pump chamber pressure increases only to a value necessary to force the water through the outlet valve against this low pressure, but as the tank pressure is increased, the pump chamber pressure will also increase. At greater pressures, however, more water will be forced back through the conduit **60**. Delivery of water to the outlet chamber during each pressure stroke is thus decreased, and the portion of each stroke during which the motor must operate to overcome the full tank pressure is decreased. Accordingly, while there is some loss in efficiency, the pump will operate automatically to provide a higher maximum delivery rate at low pressures and a higher maximum pressure at lower rates without overheating or overloading the motor.

From the foregoing discussion, it will be apparent that several of the advantages stemming from the provision of conduit **60** depend in part on the specific location of the conduit above the level of the inlet valve and approximately at the level of the outlet valve, while others of the advantages are at least partially independent of its position. For instance, the specific location of the conduit is much less important insofar as its function, just discussed, of stabilizing the motor load is concerned than in its priming function earlier considered, wherein its location above the inlet valve and below the level of the connection of the inlet conduit with the inlet chamber are of more importance.

While I have shown only certain preferred embodiments of my invention by way of illustration, many modifications will occur to those skilled in the art, and I therefore wish to have it under-

stood that I intend, in the appended claims, to cover all such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by United States Letters Patent is:

1. In a diaphragm pump, means forming a pump chamber having a top wall and a side wall comprising a substantially vertical flexible diaphragm, an inlet flap valve and an outlet flap valve in said top wall, means forming an inlet chamber and an outlet chamber each disposed above said pump chamber and arranged for periodic alternating communication therewith through said respective valves, and a conduit relatively much smaller than said inlet valve in communication between said inlet chamber and said pump chamber at least while said inlet valve is closed.

2. In a diaphragm pump, the combination in accord with claim 1 wherein said outlet valve and said conduit are each located higher than said inlet valve.

3. In a positive displacement pump, means forming a pump chamber having a top wall and a horizontally movable side wall, inlet and outlet valves mounted in the top wall of said chamber, a suction chamber separated by said inlet valve from said pump chamber, and a conduit of much smaller capacity than said inlet valve and in bypassing relation thereto.

4. In a diaphragm pump, a pump chamber having a top wall including inlet and outlet valve ports and a side wall including a movable diaphragm, said top wall being formed to dispose said inlet valve port approximately at the level of the top of the movable portion of said diaphragm and to dispose said outlet valve port at a higher level, a suction chamber and an outlet chamber communicating with said pump chamber through said respective valves, inlet and outlet valve ports, said top wall having a relatively restricted opening therethrough in bypassing relation to said inlet valve port.

5. In a positive displacement pump, a displacement chamber having a top opening, a valve assembly comprising a generally flat base plate proportioned to cover said opening and having a first portion and a second cup-shaped portion, a port in said first portion, a second port in said cup-shaped portion, said base plate and top opening being arranged to be substantially horizontally disposed to position said ports at different respective upper and lower levels, a valve plate below said base plate biased to cover said lower level port and a second valve plate above said base plate bised to cover said upper level port.

6. In a positive displacement pump, a displacement chamber having a top opening, a valve assembly comprising a generally flat base plate proportioned to cover said opening and having a first portion and a second cup-shaped portion, a port in said first portion, a second port in said cup-shaped portion, said base plate and top opening being arranged to be substantially horizontally disposed to position said respective ports at different respective levels, whereby one said port is at an upper level higher than the relatively lower level of the other said port, a valve plate below said base plate biased to cover said lower level port and a second valve plate above said base plate biased to cover said upper level port, and an opening much smaller than said ports extending through said base plate at the approximate level of said upper level port in bypassing relation to said lower level port.

7. In a positive displacement pump, a displacement chamber having a generally horizontal upper wall, said upper wall being provided with an opening, and an inlet chamber, a valve assembly comprising a generally flat base plate covering said opening, an inlet port and an outlet port extending through said base plate, a perforate resilient sheet member disposed against the lower face of said base plate to register a perforation therein with said inlet port, a second perforate resilient sheet member disposed against the upper face of said base plate to register a perforation therein with said outlet port, a valve plate for each said port biased to seat against said respective sheet members, said inlet chamber being separated from said displacement chamber by a portion of said base plate partially covered by said first sheet member and said inlet port valve plate, and an opening within the bounds of said portion of said base plate constantly in communication therethrough between said inlet chamber and said displacement chamber.

8. In a positive displacement liquid pump, a displacement chamber having a top opening, a valve assembly comprising a generally flat base plate proportioned to cover said opening, spaced perforations in said plate forming valve ports, a valve plate for each face of said base plate to cover respective distinct ones of said ports therein and spring means to bias said valve plates toward port covering positions, thereby to form an inlet and an outlet valve, a resilient sheet member disposed between each said valve plate and said base plate and having perforations to register with said ports to afford a resilient valve seat for each said valve plate, said base plate having a bypass opening through said base plate adjacent one of said ports therein which is part of said inlet valve, said bypass opening being continuously open and much more restricted than said ports.

9. In a positive displacement pump, a displacement chamber having a top opening, a valve assembly comprising a generally flat plate proportioned to cover said opening and having a cup-shaped portion, an inlet port and an outlet port extending through said plate, one of said ports being in said cup-like portion and the other spaced from said portion, movable valve members for said inlet and outlet ports, respectively, means to bias said members toward said plate to cover said respective ports, and resilient sheet means disposed between said valve members and said plate perforated to register with said ports to provide a resilient seat for each said valve member at each said port.

10. In a positive diplacement pump, an open top pump chamber and inlet and compression chambers, said inlet and compression chambers being open at the bottom and being disposed side by side above said pump chamber, a valve assembly to be interposed between said pump chamber and said inlet and compression chambers, said valve assembly comprising a metal member shaped to lie against the rim bounding the top opening of said pump chamber on one side and against the rims of said inlet and compression chambers on the other side, a first portion of said member separating said compression chamber from said pump chamber and a second portion separating said inlet chamber from said pump chamber, said first portion having a flat area on said compression chamber side and said second portion having a flat area on said pump chamber side, respective resilient seat members for each said area covering at least a portion thereof and respective-

ly disposed on respective faces of said metal members, at least two aligned ports for each said area, each said port extending through said metal member and said respective seat member, a movable valve member comprising a metal plate for each said area disposed to lie against said respective seat members to close said ports, means to spring-load said plates into port closing position and arranged to permit said ports to open in response to predetermined differential pressures on said respective plates acting in opposition to the respective spring-loading thereof, and a continuously open bypass conduit formed through said metal member communicating between said inlet chamber and said pump chamber, said bypass conduit being relatively much more restricted than said valve ports in said second portion.

11. In a positive displacement pump, an open top pump chamber and inlet and compression chambers, said inlet and outlet chambers being open at the bottom and being disposed side by side above said pump chamber, a valve assembly to be interposed between said pump chamber and said inlet and compression chambers, said valve assembly comprising a metal member shaped to lie against the rim bounding the top opening of said pump chamber on one side and against the rims of said inlet and compression chambers on other side, a first portion of said member separating said compression chamber from said pump chamber and a second portion separating said inlet chamber from said pump chamber, said first portion having a flat area on said compression chamber side and said second portion having a flat area on said pump chamber side, respective resilient seat members for each said area covering at least a portion thereof and respectively disposed on respective faces of said metal members, at least two aligned ports for each said area, each said port extending through said metal member and said respective seat member, a movable valve member comprising a metal plate for each said area disposed to lie against said respective seat members to close said ports, means

to spring-load said plates into port closing position and arranged to permit said ports to open in response to predetermined differential pressures on said respective plates acting in opposition to the respective spring-loading thereof, and a continuously open bypass conduit communicating between said inlet chamber and said pump chamber, said bypass conduit being relatively much more restricted than said valve ports in said second portion.

12. In a positive displacement liquid pump, a displacement chamber, outlet valve means for said chamber, an inlet system for said pump comprising a suction chamber to retain a volume of the liquid to be pumped, inlet valve means separating said suction chamber and said displacement chamber, and a conduit member distinct from said inlet valve means providing a passageway communicating directly between said displacement chamber and said suction chamber in bypassing relation to said inlet valve means.

13. In a diaphragm pump, a pump chamber, an inlet valve and an outlet valve closing said chamber, an inlet chamber communicating with said inlet valve and having an inlet opening above said inlet valve, said pump chamber being positioned with respect to said inlet opening to dispose at least a portion of said pump chamber below said inlet opening, a restricted, continuously open conduit communicating at a level below said inlet opening between said inlet chamber and said pump chamber.

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