Nov. 5, 1957 W. E. RUPP 2,811,929

DIAPHRAGM PUMP

Filed July 17, 1953 2 Sheets-Sheet 1

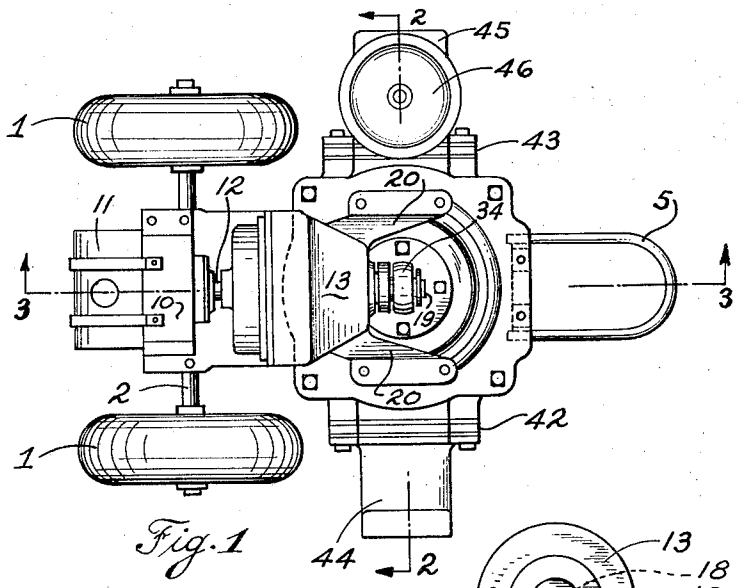


Fig. 1

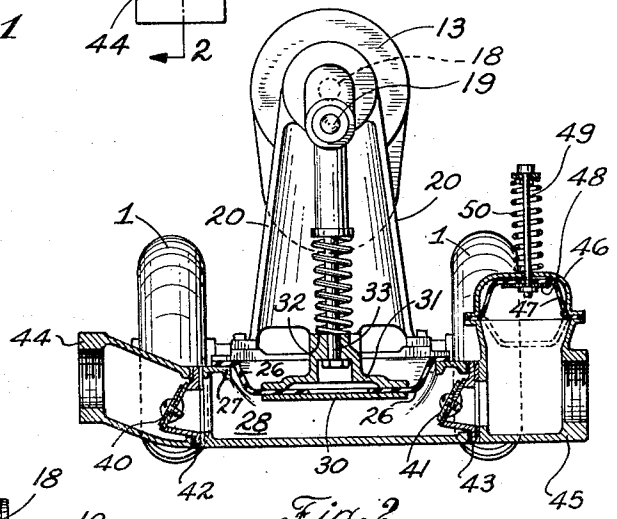


Fig. 2

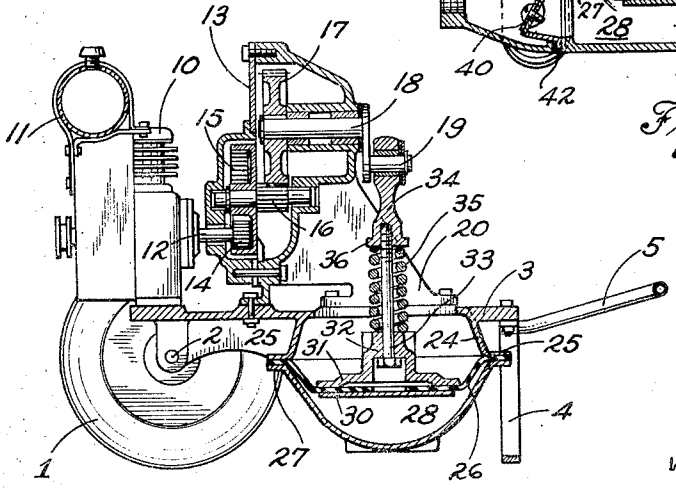


Fig. 3

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DIAPHRAGM PUMP

Filed July 17, 1953 2 Sheets-Sheet 2

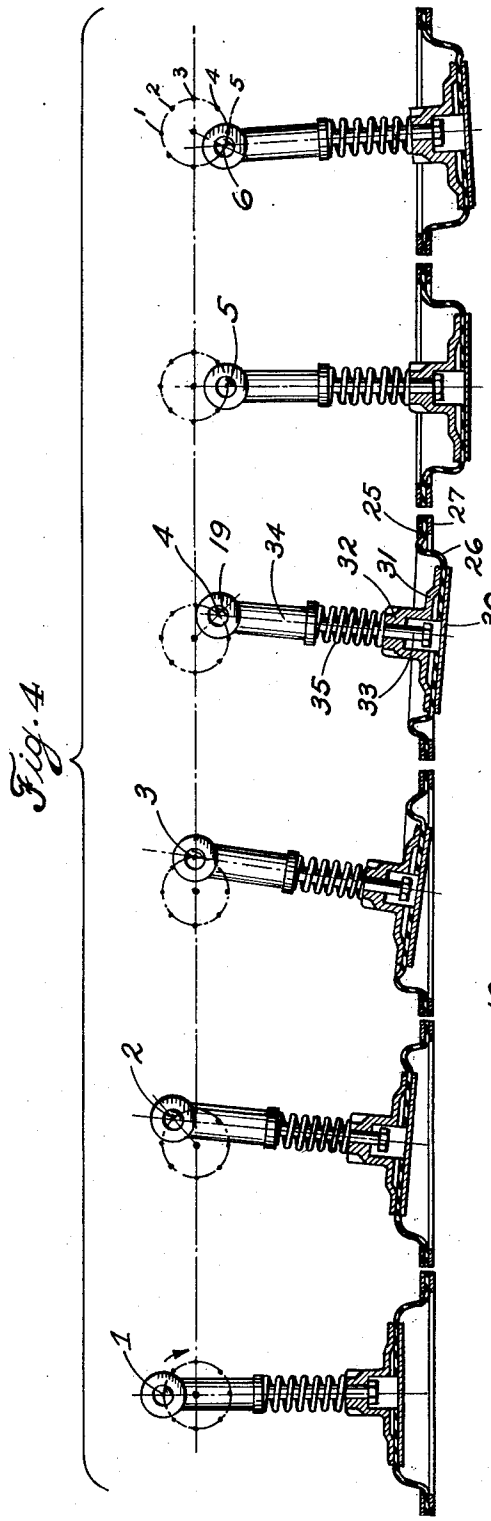


Fig. 4

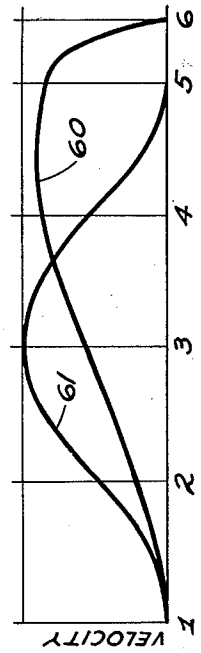


Fig. 5

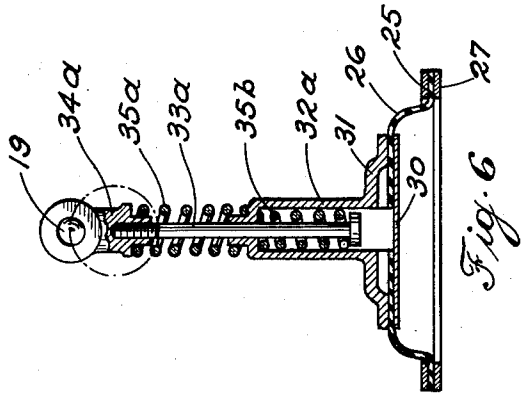


Fig. 6

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2,811,929

DIAPHRAGM PUMP

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5 Claims. (Cl. 103—150)

This invention relates generally to diaphragm pumps and is particularly concerned with a pump of that class in which the rate of flow of liquid out of the pump is accelerated throughout the discharge stroke of the diaphragm.

In the prior diaphragm pumps, the movement of the diaphragm is accelerated from zero at the beginning of the stroke to a maximum velocity at the middle of the stroke and is then decelerated at a corresponding rate to zero at the end of that stroke. This action is traceable to the fact that the diaphragm is moved by a reciprocating rod fixedly connected thereto and to a rotating crank.

As a result of this characteristic movement of the diaphragm, liquid is discharged from the pump at a rate which varies with the rate of movement of the diaphragm, that is, during the last half of the discharge stroke of the diaphragm, the volume of liquid pumped and the velocity of flow of that liquid decrease and may actually fall to zero. Important disadvantages resulting from this action are that the volume of liquid pumped is less than it should be and much energy is expended in starting the flow of liquid in the outgoing pipe line at the beginning of every discharge stroke.

One of the most common uses for a diaphragm pump is for pumping sludge and water seepage encountered on construction jobs. For this kind of use the pump is generally located at the edge of an excavation or ditch, and is fitted with a relatively long suction line to reach the ground water and sludge which is to be removed.

The inertia of the liquid at rest in the suction hose can be very great. On the suction stroke a vacuum is created by the diaphragm. The suction force combined with the external air pressure acting on the surface of the liquid at the free end of the suction hose serve to move the liquid up the hose and into the pump. Since the liquid has no tensile strength the pump diaphragm cannot exert any pull on the liquid. Hence, the only force which can be used to move the liquid up the hose is that due to atmospheric pressure.

When that pressure is inadequate to move the liquid through the suction hose at a speed sufficient to follow the movement of the diaphragm cavitation will occur, i. e., the diaphragm will pull away from the surface of the liquid and on its return stroke will contact that surface before it has moved up the suction tube as far as it would have moved if the diaphragm had not left that surface. In other words when cavitation occurs the volume and rate of flow of liquid is reduced.

The present invention aims to increase the efficiency of diaphragm pumps, both as regards the amount of liquid discharged therefrom and the amount of energy required to discharge it, and this object has been attained by the present invention which is embodied in a pump having a new combination of parts and a new mode of operation and giving new results.

Briefly stated, the present invention contemplates moving the pumping chamber diaphragm during the latter half of its discharge stroke to a greater extent than heretofore and at a speed which accelerates and is higher than the conventional rate. This acceleration and high speed contrasts sharply with the rapid decrease in rate of movement of the diaphragm which is characteristic of the prior art, and results in increasing the rate of flow of fluid out of the pump throughout substantially the entire discharge stroke to a maximum rate near the end of that stroke. This high rate of flow and the inertia of the flowing liquid causes the flow to continue after the crank reaches its lowest position. The unrestrained, unsupported part of the diaphragm which lies between the clamps at its outer periphery and at its center is free to, and does, move with the outgoing liquid even after the crank reaches its lowermost position. This additional movement of liquid and diaphragm results in a greater pumping capacity than pumps of prior art.

The tendency to cavitation may be substantially overcome by the addition of an auxiliary chamber located in the suction line outside of the pumping chamber but near the inlet valve.

The present invention will be better understood from the following description and reference to the accompanying drawings in which:

Fig. 1 is a top plan view of a pump embodying the present invention and moutned on a vehicle equipped with means for actuating the diaphragm of the pump;

Fig. 2 is a vertical, sectional view partly in elevation taken on line 2—2 of Fig. 1;

Fig. 3 is a vertical, sectional view partly in elevation taken on line 3—3 of Fig. 1;

Fig. 4 shows the diaphragm of the pump and its associated parts in various positions they occupy during the discharge stroke of the pump; and

Fig. 5 shows curves illustrating the rates of flow of liquid from a conventional diaphragm pump and from a pump embodying the present invention.

Fig. 6 is a central sectional view showing a modified form of diaphragm actuating means which may be substituted for that shown in Figs. 2 and 3.

In the drawings, the wheels 1 and their axle 2 support one end of a plate-like platform 3 which has a support 4 at the end opposite the wheels and a handle 5 by which the device may be moved about on the wheels 1. Disposed on plate 3 above axle 2 is a conventional internal combustion engine 10 and a fuel tank 11. The shaft 12 of motor 10 projects into a gear box indicated generally at 13 and has affixed thereto a gear 14 which, through a train of gears 15, 16 and 17, rotates shaft 18 and crank 19. The gear case 13 is supported on plate 3 intermediate its ends and is braced longitudinally of plate 3 by integral side wings 20.

Near the handle end of plate 3 and beneath crank 19, plate 3 is formed with a downwardly extending annular flange 24 having a generally flat annular bottom edge 25. A flexible diaphragm 26 is positioned with its edge portions between the bottom edge 25 and the opposed edge of pan 27 and these parts are secured together in any suitable way, as by bolts extending through their edges. Pan 27 and diaphragm 26 define a pumping chamber 28.

Diaphragm 26 is provided with a central reinforcing means in the form of a push-pull clamp consisting of a lower plate 30 and an upper plate 31, these plates being secured against opposite sides of diaphragm 26 by any suitable means. It will be noted that a ring-like part of the diaphragm, i. e. that part between its outer anchored edge portion and its central reinforced and supported portion, is unrestrained and unsupported and hence is capable of flexing readily in response to positive or negative pressure. In other words, it may move freely with liquid flow into or out of the pumping chamber.

The upper plate 31 of the clamp has an upstanding boss 32 through which a headed rod 33 extends. The head

on the rod and the boss constitute a lost motion connection of the rod to the diaphragm. The upper end of this rod is attached to an extension 34 which is mounted on crank 19. A spring 35 is coiled around rod 33 and at opposite ends presses against a shoulder or abutment 36 on the extension 34 and against boss 32 of the clamp. It will be noted that spring 35 acts as a resilient filler between the clamp and the abutment by reason of which the rod may move with and relative to the clamp during the discharge strokes and with it during the suction strokes.

The pumping chamber 28 is provided with an outlet controlled by a check valve 40 and with an inlet controlled by a similar check valve 41. As shown, these two check valves are embodied in separate plates 42 and 43, respectively, which are attached to the ends of pan 27, as is better shown in Fig. 2. A pipe connection 44 is attached to plate 42 and an inlet fitting 45 is attached to plate 43. It will be understood that plates 42 and 43 may be made integral with pan 27 and also with connections 44 and 45 if desired.

Fitting 45 is adapted for connection to a pipe line extending to the supply of fluid to be pumped, which line is usually flexible. This fitting 45 may be simply a tube but preferably is enlarged by being extended upwardly, thereby providing an auxiliary chamber of considerable volume from which liquid may be drawn during the suction stroke of the pump and into which liquid to be pumped may flow during the discharge stroke of the pump. This enlargement of fitting 45 includes an upward extension of the fitting itself and a dome-shaped cover 46. If desired a diaphragm 47 may extend across the chamber with its edges held in place between the upper end of the fitting and the lower edges of the cover 46. As shown, this diaphragm is fitted with central clamping plates 48 and a rod 49 which extends up through the diaphragm and cover 46 and is urged upwardly by spring 50 coiled therearound and pressing against the top of cover 46.

Although a pump equipped with the diaphragm 48, rod 49 and spring 50 has been found to give results superior to those obtainable with a diaphragm pump not equipped with the auxiliary chamber, even better results are obtainable when that diaphragm, rods and spring are omitted from the auxiliary chamber of Fig. 2.

In Figs. 4 and 5, the various positions of the crank are indicated by numerals 1 to 6 inclusive, 1 representing the position at the beginning of the discharge stroke, 3 at the middle thereof and 5 at the completion of the discharge stroke. Numerals 2 and 4 represent points midway between 1 and 3 and 3 and 5 respectively, while 6 represents a point about 20° beyond point 5. As is indicated in Fig. 4, rotation of crank 19 downwardly moves rod 33 and its extension 34 downwardly at a rate which increases from zero at position 1 to a maximum at position 3 and then decreases at a comparable rate from position 3 to position 5. As soon as this discharge stroke begins, the rod 1 moves endwise relative to the diaphragm clamp with resultant compression of spring 35. This compression increases from the minimum when the crank is in position 1 to the maximum at or just beyond position 3. During this time force is being applied through the diaphragm to fluid in the pumping chamber 28 with expulsion of that fluid through outlet check valve 40, inlet check valve 41 being closed at the beginning of the downward movement of the diaphragm.

When the crank proceeds beyond position 3 and its rate of movement decreases, the compressive force applied by the rod to spring 35 decreases and the resistance of the liquid to expulsion from the chamber also doubtless decreases because of the fact that the liquid is then in motion with the net result that spring 35 begins to expand. Such expansion proceeds throughout the remainder of the discharge stroke, possibly at an increasing rate during part of that time, and until the clamp plate 31 has come into engagement with the headed end of rod 33 which takes place at position 5 of the crank. Thereafter, instead of applying compression forces to rod 35, crank 19 applies tension forces to the rod during the suction stroke and moves the diaphragm back to the position it occupies at the beginning of the discharge stroke.

Because of the presence of the resilient filler 35 between the abutment 36 and the diaphragm clamp and the expansion of filler 35 which takes place during the latter half of the discharge stroke, the diaphragm continues to move at an increasing rate of speed during the last half of the discharge stroke, i. e., it moves at a rate considerably higher than is possible with conventional diaphragm pumps where the rate of movement is controlled entirely by the rotation of the crank. As a result of this increasing rate of movement of the diaphragm, the rate of flow of liquid out of the discharge chamber is increased throughout substantially the entire discharge stroke and reaches its maximum rate of flow near the end of the discharge stroke.

In Fig. 5, curve 60 illustrates the speed of flow of the liquid discharged from the pumping chamber as the diaphragm proceeds from crank positions 1 to 6. As this curve shows, the outgoing liquid flows at a velocity which constantly increases or accelerates from zero at crank position 1 to a maximum near to position 5, i. e., at the end of the discharge stroke as the curve shows. The flow of liquid does not cease but continues to flow during the first part of the suction stroke, i. e., to about position 6 of the crank. Curve 61 of Fig. 5 illustrates the typical flow curve of a conventional diaphragm pump. As this curve shows, the velocity of the liquid being discharged increases from zero at crank position 1 to a maximum at crank position 3 and then decreases at a corresponding rate to position 5. While the maximum velocity of fluid flow indicated by curve 61 is slightly higher than the maximum shown by curve 60, the duration of flow is much less with a correspondingly greater time interval for the flow to decelerate.

As the diaphragm clamp reaches its lowermost position, i. e., 5 in Fig. 4, the unsupported part of the diaphragm, i. e., the ring-shaped part between the central clamp and the peripheral secured edge portion, continues to move downwardly and outwardly following the liquid which is flowing out of the pumping chamber at its greatest velocity and with its maximum inertia. This downward movement is stopped and upward movement is started when the crank is approximately at position 6 but at that time outlet valve 40 has closed. This action of the diaphragm is indicated at position 5 in Fig. 4 where the diaphragm is still bulged upwardly, and at position 6 where it has bulged down to its lowermost position.

A notable result of the continued downward movement of the unsupported part of the diaphragm is that the inertia of the outflowing liquid is not diminished by the creation of a vacuum like condition between the fluid and the diaphragm prior to and just after the clamp reaches its lowermost position. Similarly the inertia of the incoming liquid is not opposed by that part of the diaphragm prior to and just after the clamp reaches its upmost position.

The foregoing operation is quite different from that of the conventional diaphragm pump. In such a pump the unsupported part of the diaphragm never reaches its lowest possible position because of the back pressure of the fluid which bulges that part of the diaphragm upwardly and which is due to the decrease in velocity of the liquid flowing out of the pumping chamber during the second part of the discharge stroke.

Thus to summarize, it may be said that the speed of the outgoing water is gradually increased throughout nearly all the discharge stroke; that the flow continues even after the suction stroke begins; and that the unsupported part of the diaphragm continues to move downwardly and outwardly after the central clamped part of the diaphragm reaches its lowermost position. In contrast therewith the conventional diaphragm discharges

fluid at a rate of speed which gradually increases to a maximum during the first half of the discharge stroke and then gradually decreases substantially to zero during the second half of that stroke; and that the unsupported part of the diaphragm never reaches its lowermost possible position.

Fig. 6 shows a modified form of diaphragm actuating mechanism. In this device the crank **19** is rotatably mounted in an extension **34***a* to which headed rod **33***a* is attached. This rod extends through the boss **32***a* of diaphragm clamp **31** and is surrounded by springs **35***a* and **35***b*. Spring **35***a* presses at its upper end against extension **34***a* and at its lower end against boss **32***a* while spring **35***b* presses at its upper end against boss **32***a* and at its lower end against the head on rod **33***a*. These springs may be pre-loaded if desired.

The operation of a pump equipped with the apparatus of Fig. 6 is quite like that described above but, due to the fact that crank **19** exerts force on the diaphragm through spring **35***b* during the suction stroke, the rate of flow of liquid into the pumping chamber will be increased during the suction stroke; and the unsupported part of the diaphragm will move to its upmost possible position at or just after the time the central clamp has reached its upmost position with resultant tendency to continue the inflow of liquid into the first part of the discharge stroke.

The above described operation takes place whether fitting **45** lacks or includes an auxiliary chamber, or has such a chamber provided with a spring urged diaphragm. However, the presence of such a chamber, diaphragm and spring give better results than when that chamber is absent, and comparable results are obtained by using the auxiliary chamber without its diaphragm.

The operation of the above described apparatus, when equipped with the auxiliary chamber, is substantially as follows: Assuming that the pump has been primed, that the auxiliary chamber is substantially filled with liquid, that the diaphragm is at position 6 in Fig. 4, and that the outlet valve **40** has just closed, the upward movement of diaphragm **26** tends to create a condition of vacuum in the pumping chamber and thereby opens inlet valve **41**, whereupon liquid is drawn into the pumping chamber from the auxiliary chamber. As this liquid is drawn out of the auxiliary chamber it tends to create a vacuum condition in the auxiliary chamber, thus exerting a suction force on the liquid in the suction line and correspondngly decreasing the amount of atmospheric pressure required to be exerted on the liquid to cause it to flow in the suction line toward the pump. As more and more liquid is drawn from the auxiliary chamber, more and more suction force is applied and as the liquid moves, more and more of the atmospheric pressure is effective to accelerate the rate of movement of the liquid in the suction line toward the pump. Thus moving liquid from the auxiliary chamber to the pumping chamber tends first to assist in starting movement of liquid in the suction line and then to increase the velocity of that flow. The auxiliary chamber is partially emptied of liquid during the first half of the suction stroke, but the condition of vacuum existing therein continues to exert its force on the liquid in the suction line during the last half of the suction stroke while the diaphragm is deceleratng due to the motion of the crank. Thus, during the second half of the suction stroke, liquid continues to flow into the auxiliary chamber, partly by reason of its inertia and also partly due to the combined forces of vacuum and atmospheric pressure, until the auxiliary chamber has been filled, and in some instances to flow on into the pumping chamber after substantially complete filling of the auxiliary chamber. In the event that the auxiliary chamber has not been susbtantially filled with liquid when the inlet valve **41** into the pumping chamber is closed and the diaphragm begins its discharge stroke, the flow of liquid in the suction line will continue until the auxiliary chamber has been substantially filled and for the reasons just stated.

It will be understood from the foregoing description that by providing an auxiliary chamber with its considerable supply of liquid closely adjacent to the pumping chamber, and with its tendency to prevent cavitation, and with the addition of the vacuum or suction effect to the force of atmospheric pressure, the flow of liquid in the suction line toward the pump has, in contrast to prior diaphragm pumps lacking an auxiliary chamber, been accelerated during the suction stroke of the pump, has begun to flow sooner after the beginning of the suction stroke, and has continued to flow after the end of the suction stroke. These several differences add up to the flow of an increased amount of liquid per unit of time in the suction line and with the expenditure of correspondingly less force in overcoming the inertia of liquid at rest in the suction line. The net result of the above described new discharging operation, plus the just described new suction operation, is a marked increase in the volume of liquid pumped per unit of time and per unit of power.

When the auxiliary chamber is equipped with the diaphragm, rod and spring of Fig. 2, the operation is somewhat different than has just been described. Part of the vacuum creating force applied by the pumping diaphragm to the auxiliary chamber within fitting **45** is offset by the resistance offered by spring **50** to downward movement of diaphragm **47**. This offsetting action seems to retard the rate at which the liquid flows from the chamber into the pumping chamber. It also appears that this disadvantage is not compensated for by the suction creating effect of the outward movement of diaphragm **47** under the urging of spring **50**. For these reasons, it is preferable to use an auxiliary chamber without a diaphragm such as **47** and its associated parts.

When the diaphragm and parts shown in Fig. 6 are substituted for the corresponding parts of Figs. 2 and 3, and the suction stroke is thereby effectively prolonged to a position about midway between positions 1 and 2 in Fig. 4, there is a marked tendency for liquid to flow into the pumping chamber until after the diaphragm starts on the discharge stroke; and for the rate of flow of liquid into the pumping chamber and incidentally, in the suction line, to be accelerated throughout the suction stroke after the manner indicated in Fig. 5 and above described, with reference to the flow of liquid out of the pumping chamber during the discharge stroke.

Since two springs, **35***a* and **35***b*, are employed in the apparatus Fig. 6, they may be loaded to obtain the desired results or to compensate for existing conditions. In the case of high discharge heads or pressures, i. e., where the liquid discharge line extends to a considerable distance above the pump, upper spring **35***a* would be fairly stiff or heavily loaded. When the suction head is fairly high, i. e., the level of the liquid to be pumped is a considerable distance below the pump, the lower spring **35***b* should be fairly stiff or heavily loaded. When the pressure head is higher than the suction head, spring **35***a* should be stiffer or more heavily loaded than **35***b*, and vice versa. Thus the springs **35***a* and **35***b* may be adjusted to adapt the pump to existing conditions for accomplishing the best results.

It will be understood that the terms "spring" and "resilient filler," as used herein, are intended to mean and include any resilient means which is capable of operating like, and obtaining the results of, spring **35**.

Having thus described this invention in such full, clear, concise and exact terms as to enable any person skilled in the art to which it pertains to make and use the same, and having set forth the best mode contemplated of carrying out this invention, I state that the subject-matter which I regard as being my invention is particularly pointed out and distinctly claimed in what is claimed, it being understood that changes not amounting to invention may be made in the above specifically described

embodiments of the invention without departing from the invention as set forth in what is claimed.

What is claimed is:

1. In a diaphragm pump of the discharge and suction stroke type, a pump body having a wall partly defining a pumping chamber provided with a valved liquid inlet and a valved liquid outlet, and means to initiate and resiliently to increase the rate of flow of liquid out of said chamber, said means including a reciprocable rod supported by said body and located to reciprocate toward and away from said chamber, a rotatable crank connected to the rod to reciprocate it through the discharge and suction strokes, an abutment on the rod, a diaphragm having a connection to the rod for reciprocation thereby, said connection providing lost motion on reciprocation of said rod toward said chamber, said diaphragm having its periphery attached to said body, forming part of the wall of said chamber and having reinforcing means secured to its mid-portion, and a spring around said rod pressed between said abutment and said reinforcing means, said spring being of such strength as to be compressed by relative movement of the diaphragm and the abutment during the first part of the discharge stroke of said rod and yet cause some inward movement of said diaphragm so that the flow of liquid out of the chamber is initiated and being of such strength as to expand during the latter part of the discharge stroke after the out-flow of liquid has been initiated and to urge the diaphragm toward the chamber and to increase the rate of flow of liquid out of the chamber until near the end of the discharge stroke.

2. In a diaphragm pump of the discharge and suction stroke type, a pump body having a wall partly defining a pumping chamber provided with a valved liquid inlet and a valved liquid outlet, and means to initiate and resiliently to increase the rate of flow of liquid out of said chamber, said means including a reciprocable rod supported by said body and located to reciprocate toward and away from said chamber, an abutment on the rod, a diaphragm having a connection to the rod for reciprocation thereby, said connection providing lost motion on reciprocation of said rod toward said chamber, said diaphragm having its periphery attached to said body, forming part of the wall of said chamber and having reinforcing means secured to its mid-portion, and a spring around said rod pressed between said abutment and said reinforcing means, said spring being of such strength as to be compressed by relative movement of the diaphragm and the abutment during the first part of the discharge stroke of said rod and yet cause some inward movement of said diaphragm so that the flow of liquid out of the chamber is initiated and being of such strength as to expand during the latter part of the discharge stroke after the out-flow of liquid has been initiated and to urge the diaphragm toward the chamber and to increase the rate of flow of liquid out of the chamber until near the end of the discharge stroke.

3. In a diaphragm pump of the discharge and suction stroke type, a pump body having a wall partly defining a pumping chamber provided with a valved liquid inlet and a valved liquid outlet, and means to initiate and resiliently to increase the rate of flow of liquid out of said chamber, said means including a reciprocable rod supported by said body and located to reciprocate toward and away from said chamber, an abutment on the rod, a diaphragm having a connection to the rod for reciprocation thereby and movement relative thereto, said diaphragm having its periphery attached to said body, forming part of the wall of said chamber and having reinforcing means secured to its mid-portion, and a spring around said rod pressed between said abutment and said reinforcing means, said spring being of such strength as to be compressed by relative movement of the diaphragm and the abutment during the first part of the discharge stroke of said rod and yet cause some inward movement of said diaphragm so that the flow of liquid out of the chamber is initiated and being of such strength as to expand during the latter part of the discharge stroke after the out-flow of liquid has been initiated and to urge the diaphragm toward the chamber and to increase the rate of flow of liquid out of the chamber until near the end of the discharge stroke.

4. In a diaphragm pump of the discharge and suction stroke type, a pump body having a wall partly defining a pumping chamber provided with a valved liquid inlet and a valved liquid outlet, and means to intiate and resiliently to increase the rate of flow of liquid out of said chamber, said means incluuding a reciprocable rod supported by said body and located to reciprocate toward and away from said chamber, an abutment on the rod, a diaphragm having a connection to the rod for reciprocation thereby, said diaphragm having its periphery attached to said body, forming part of the wall of said chamber and having reinforcing means secure to its mid-portion, and a spring pressed between said abutment and said reinforcing means, said spring being of such strength as to be compressed by relative movement of the diaphragm and the abutment during the first part of the discharge stroke of said rod and yet cause some inward movement of said diaphragm so that the flow of liquid out of the chamber is initiated and being of such strength as to expand during the latter part of the discharge stroke after the out-flow of liquid has been initiated and to urge the diaphragm toward the chamber and to increase the rate of flow of liquid out of the chamber until near the end of the discharge stroke.

5. In a diaphragm pump of the discharge and suction stroke type, a pump body having a wall partly defining a pumping chamber provided with a valved liquid inlet and a valved liquid outlet, and means to initiate and resiliently to increase the rate of flow of liquid out of said chamber, said means including a rigid rod, means to reciprocate said rod toward and away from said chamber during the discharge and suction strokes of the pump respectively, a diaphragm having its outer periphery attached to the body, partly defining said chamber and having reinforcing means secured to its mid-portion, an abutment disposed opposite to and spaced apart from said diaphragm, and a spring, said rod, rod reciprocating means and abutment being supported by said body and said spring being disposed between, engaging and compressed by said reinforcing means and said abutment, said diaphragm being reciprocable and movable relative to said rod and abutment when said rod is reciprocated, said spring being of such strength as to be compressed during the first part of the discharge stroke by movement of the rod toward the chamber and by relative movement of the diaphragm and abutment so that the flow of liquid out of the chamber is initiated and being of such strength as to expand during the latter part of the discharge stroke after the out-flow of liquid has been initiated and to urge the diaphragm toward the chamber and to increase the rate of flow of liquid out of the chamber until near the end of the discharge stroke.

References Cited in the file of this patent

UNITED STATES PATENTS

1,944,340	Zubaty	Jan. 23, 1934
1,981,667	Rockwell	Nov. 20, 1934
2,254,174	Edwards	Aug. 26, 1941

FOREIGN PATENTS

350,817	Great Britain	June 18, 1931
520,903	Great Britain	May 7, 1940