

[54] **AIR PRESSURE ACTUATED SINGLE-ACTING DIAPHRAGM PUMP**
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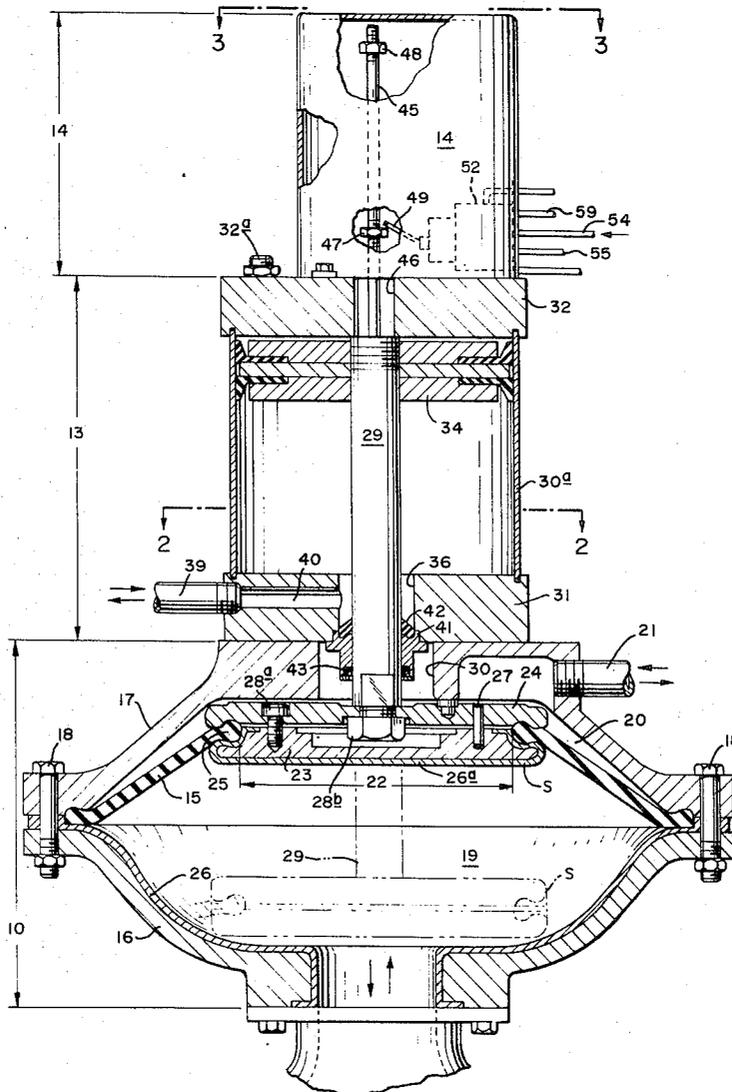
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 [58] Field of Search..... 417/394, 395, 398, 417/399, 400; 91/314; 92/100, 103

[57] **ABSTRACT**

A single-acting fluid pressure actuated diaphragm pump wherein a high suction lift is attainable by connecting the pump diaphragm to a piston or auxiliary diaphragm operating in an auxiliary fluid pressure-actuated chamber connected to the pump housing, and equipped with a control system for maintaining the pump operating cycle, which control system in turn is actuated by the pump diaphragm.

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3 Claims, 14 Drawing Figures



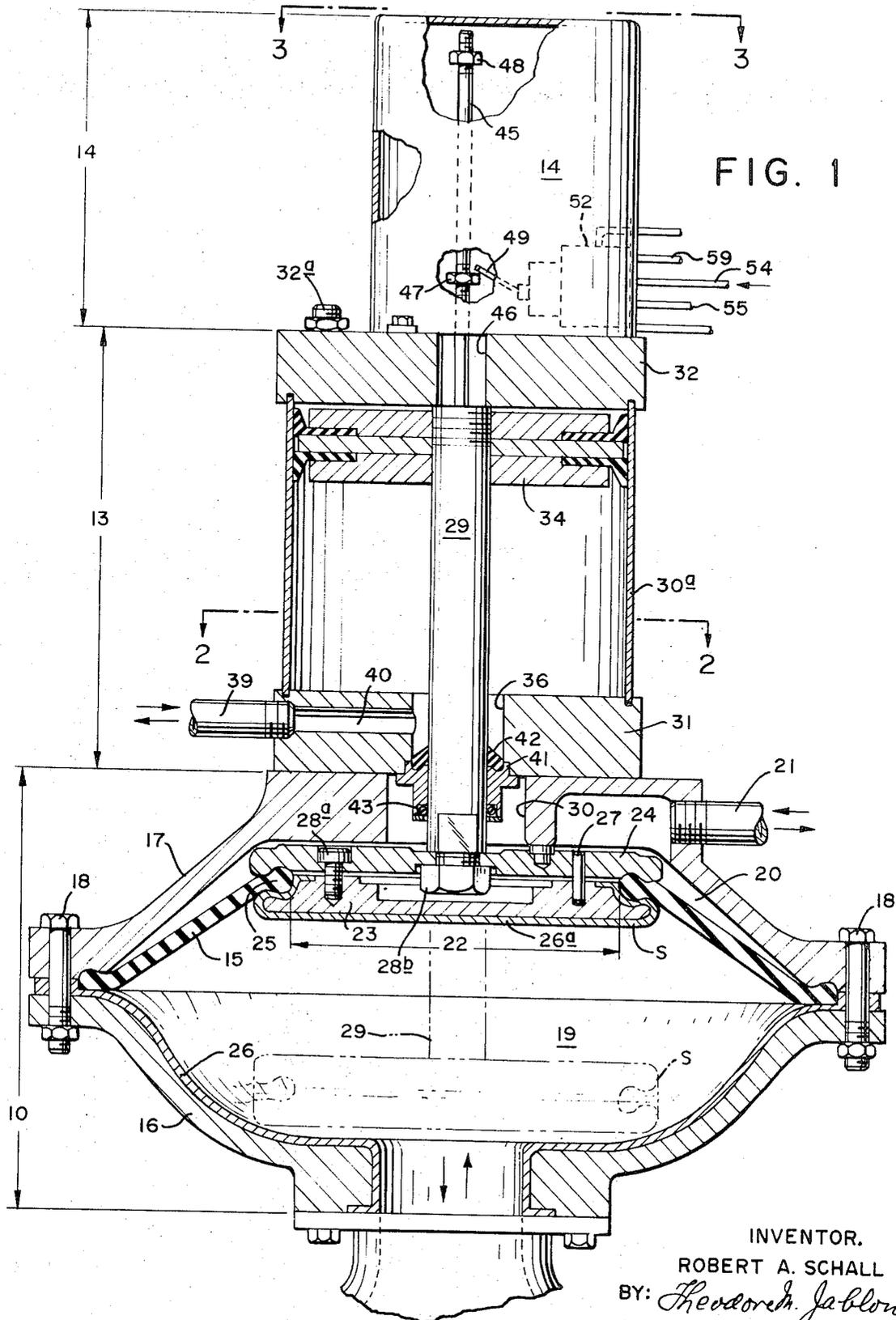


FIG. 1

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FIG. 5

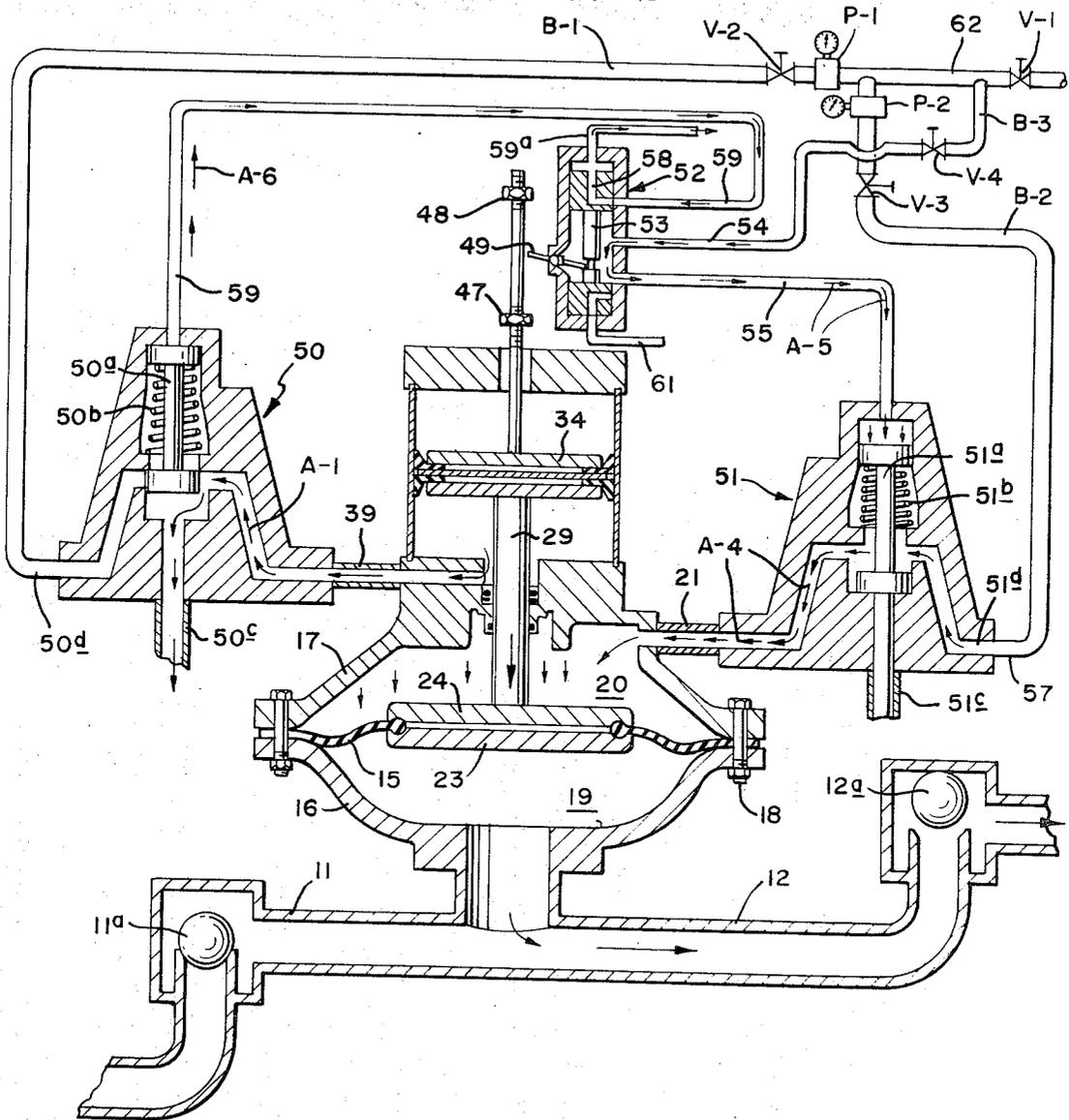


FIG. 2

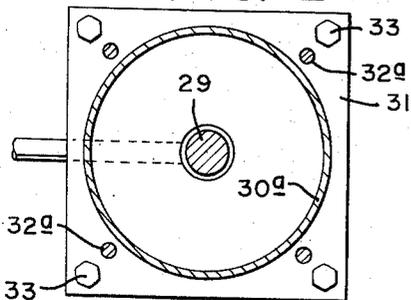
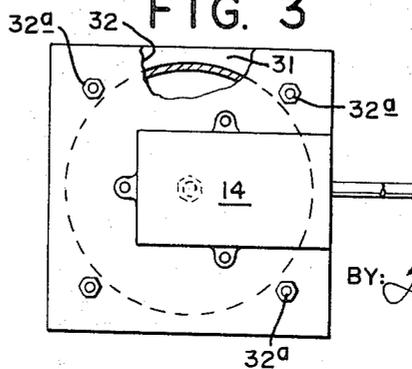


FIG. 3



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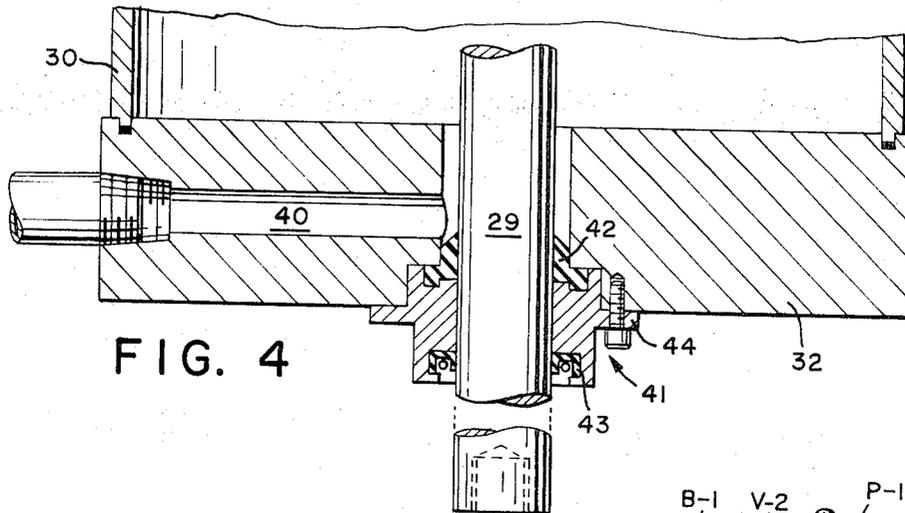


FIG. 4

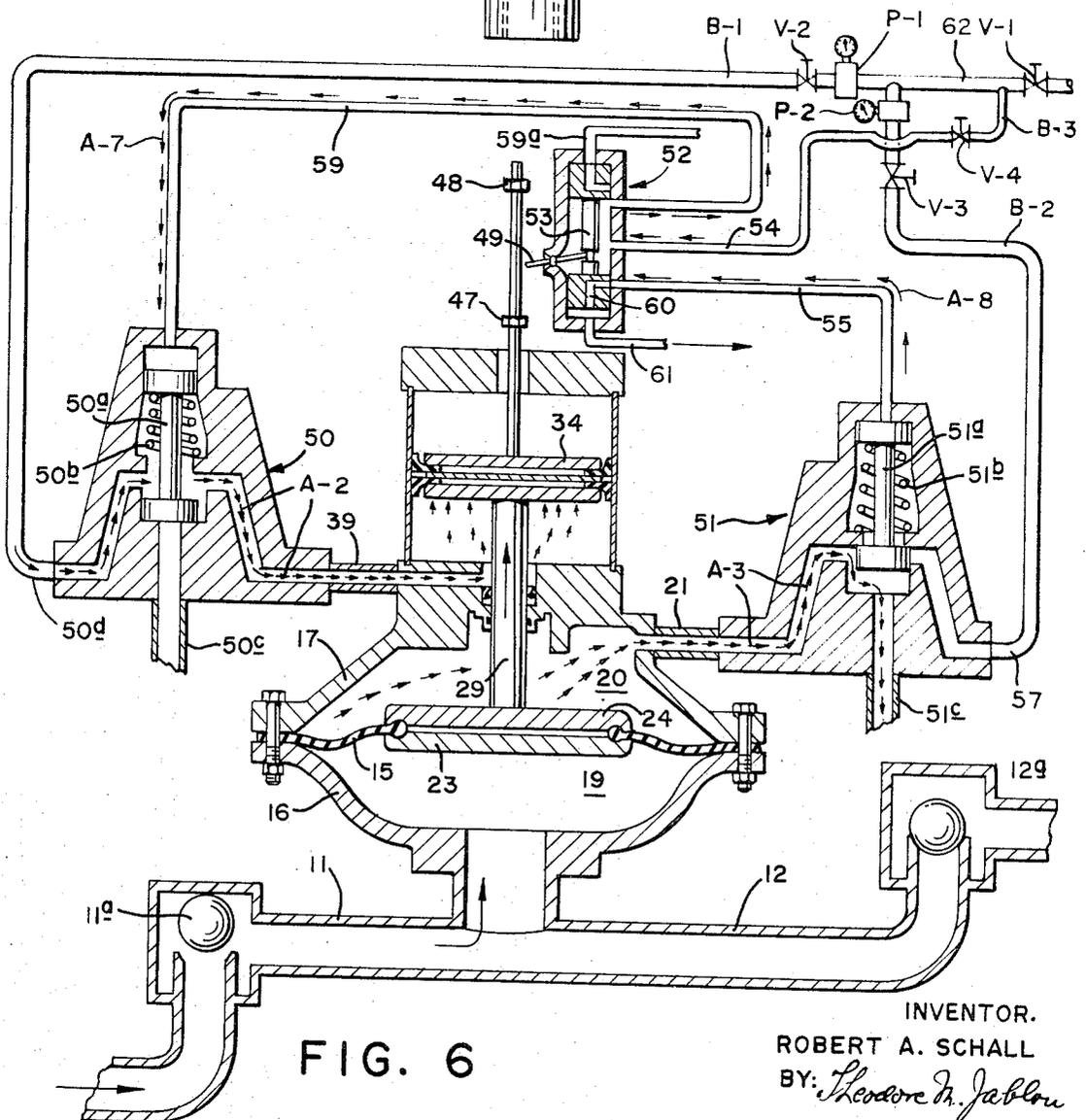


FIG. 6

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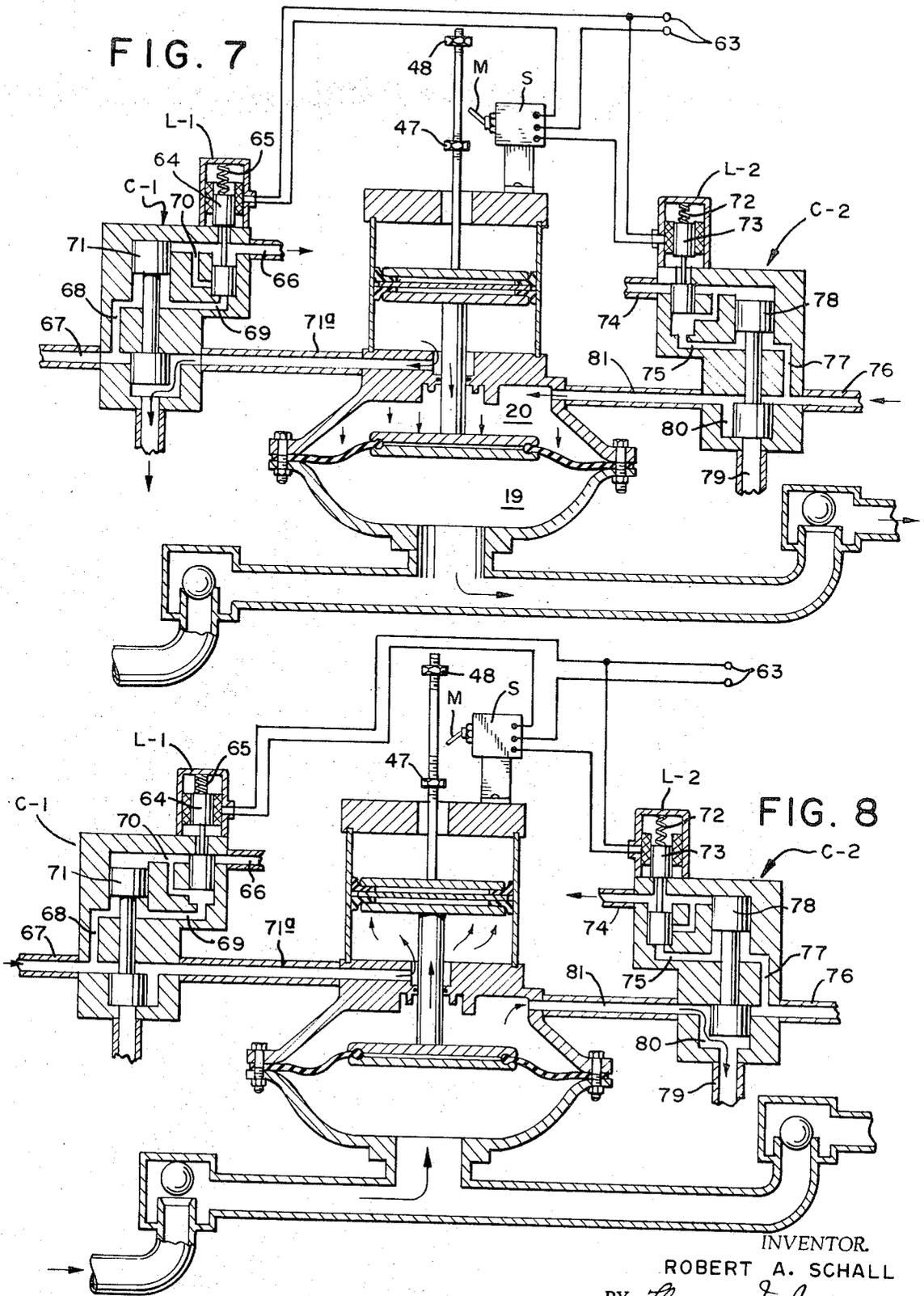
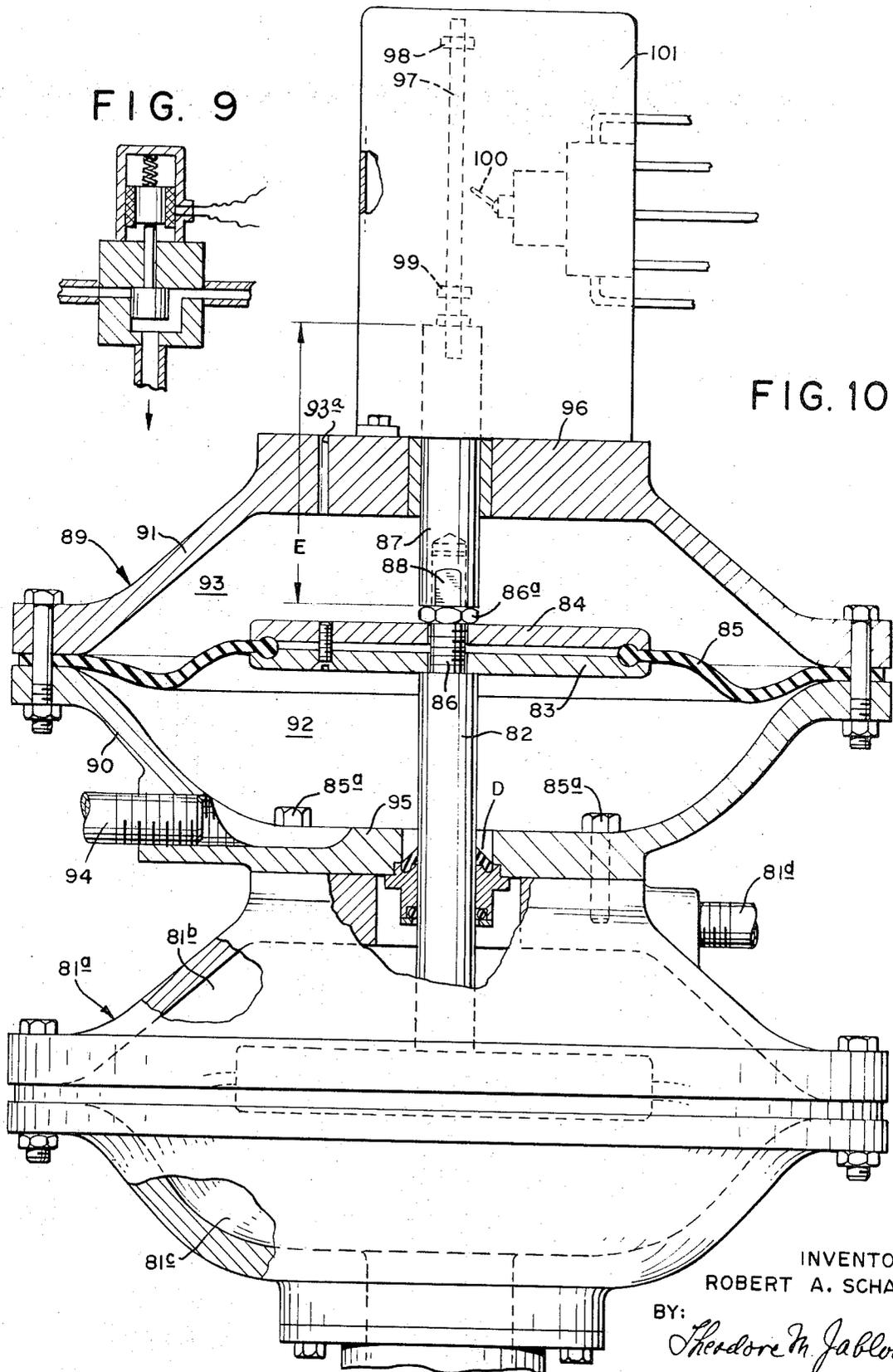


FIG. 7

FIG. 8

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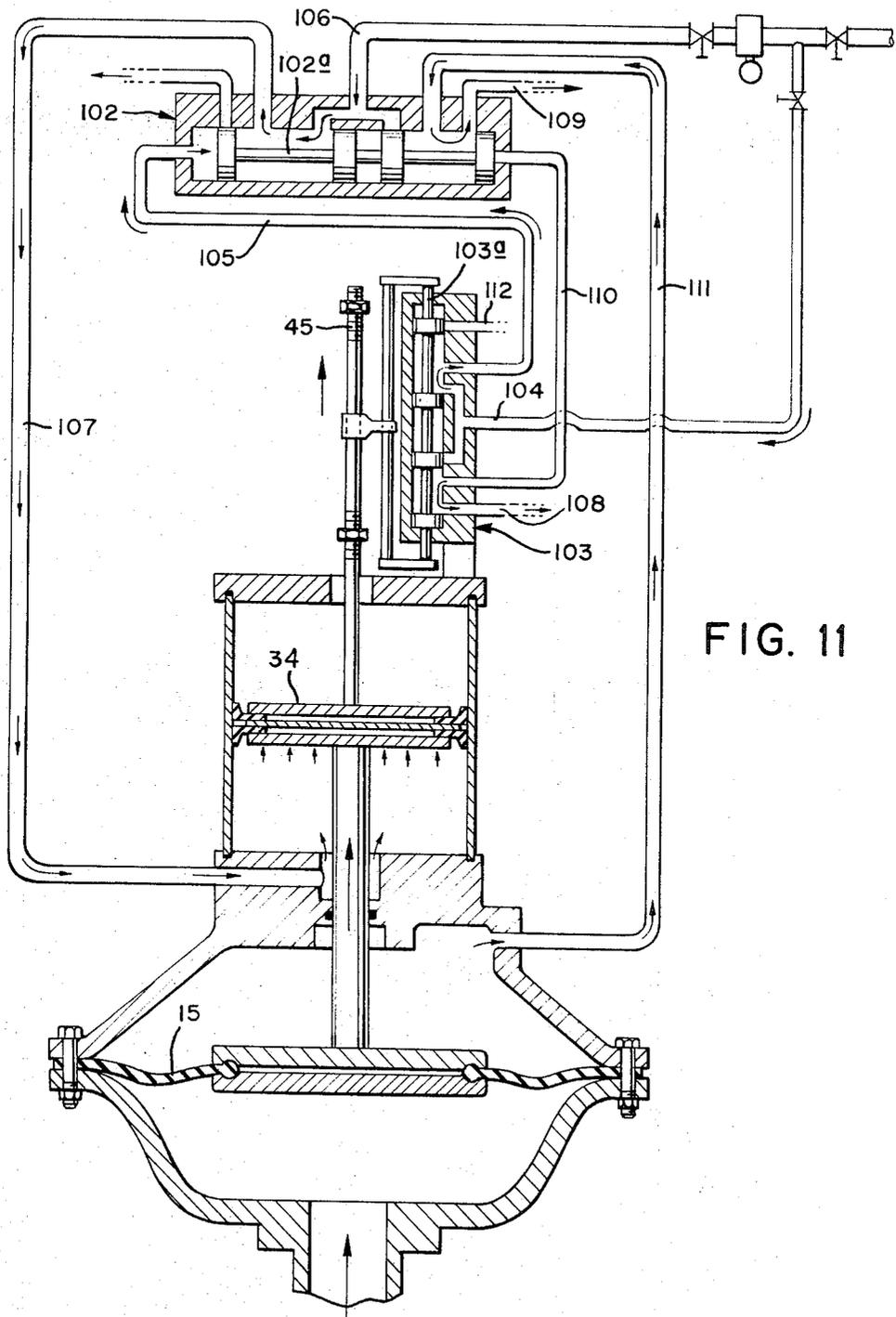


FIG. 11

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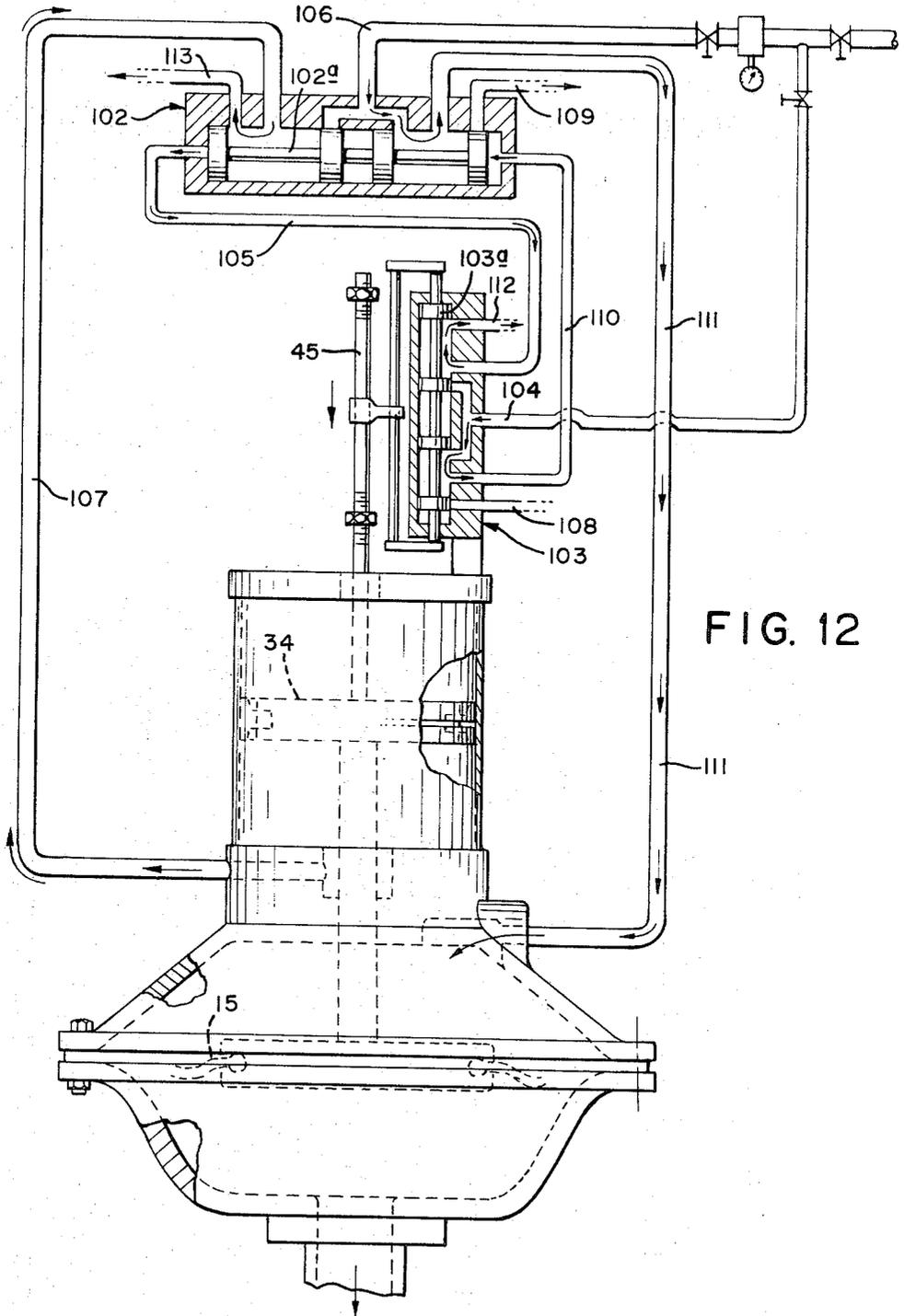


FIG. 12

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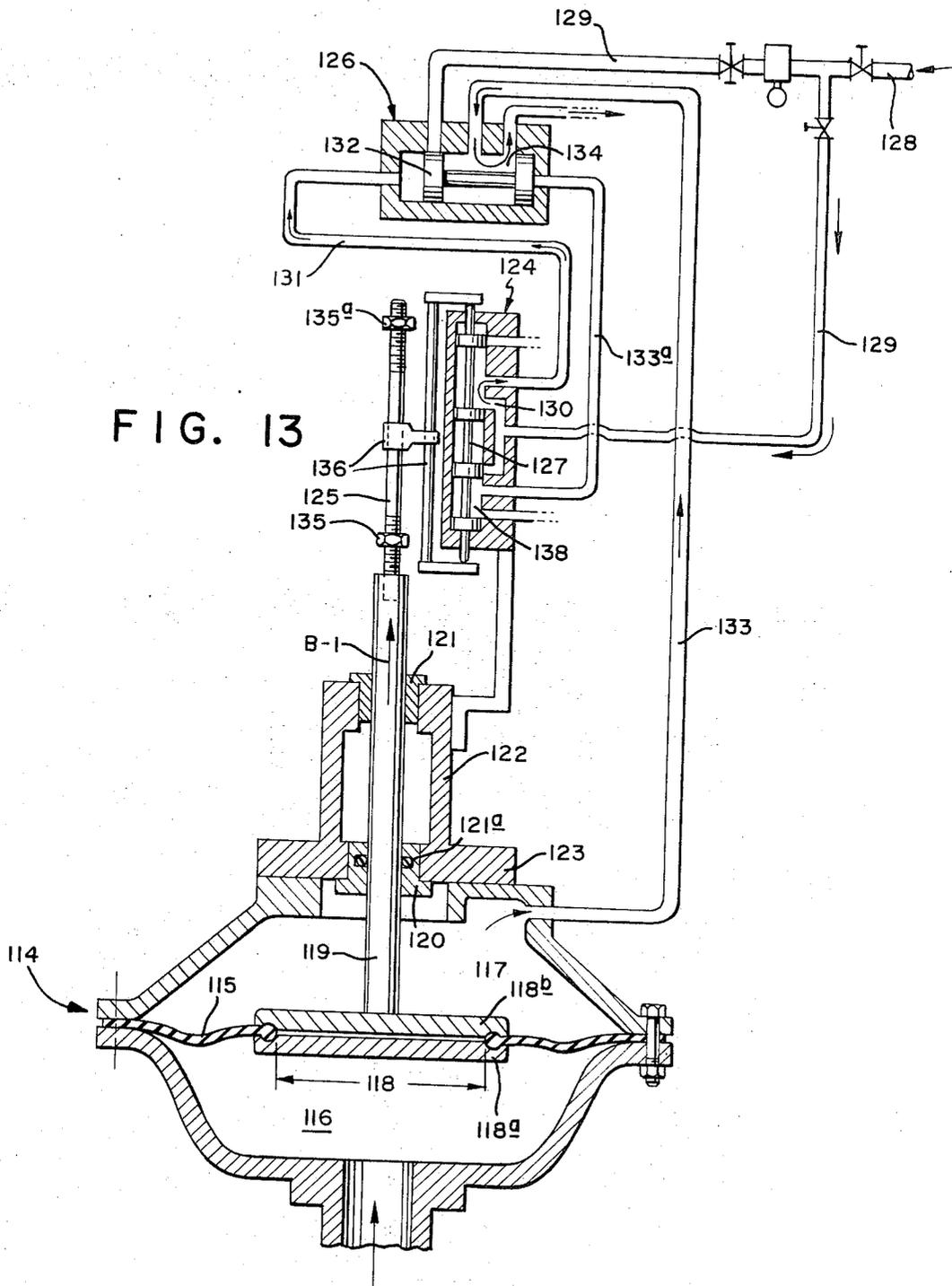


FIG. 13

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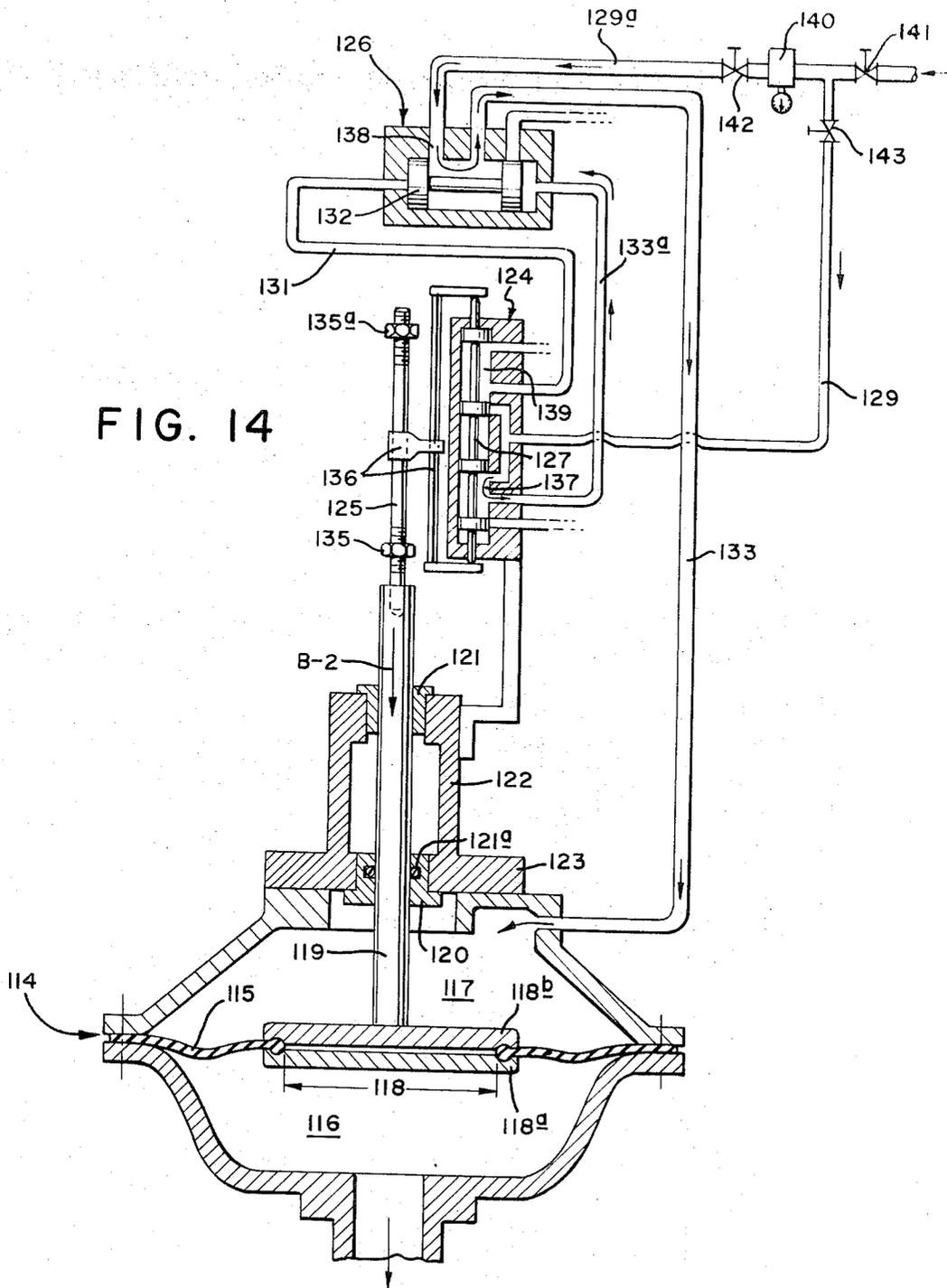


FIG. 14

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AIR PRESSURE ACTUATED SINGLE-ACTING DIAPHRAGM PUMP

This invention relates to a diaphragm pumps and pumping systems embodying a diaphragm pump. Such pumps are well suited and reliable for handling sludges and slurries, for example, sewage sludges and metallurgical pulps. These volumetrically effective displacement pumps are relatively immune to wear and tear by the slurry solids, and are self-priming when installed with a negative suction head. Also, their capacity and mode of operation are readily adjustable by adjusting the length and/or frequency of the pumping stroke.

Thus the diaphragm pumps, as a class, are distinct from rotary pumps such as centrifugal pumps or Moyno pumps or other rotating pumps which as a class are subject to wear and tear due to the rotation of the parts and the sealing means required, especially where abrasive materials are being handled.

More in particular, this invention relates to fluid pressure-actuated diaphragm pumps wherein a diaphragm divides the pump housing into a pumping chamber at one side of the diaphragm and a pump actuating chamber at the opposite side thereof. In a conventional diaphragm pump of this type, the pumping — or delivery stroke is effected by means of a fluid pressure medium such as air admitted into the actuating chamber, which moves the free floating diaphragm so as to displace the contents of the pumping chamber against a pumping head. Thus, diaphragm stresses are compensated irrespective of the height of the pumping head.

The return stroke may be effected either by gravity filling of the pump chamber under positive suction head, while the actuating chamber is being vented, or else by the application of vacuum to the actuating chamber for effecting or assisting the return stroke of the pumping cycle. The vacuum facility although costly to provide and operate, is nevertheless limited in its effectiveness. A control system usually including a timing device regulates the admission of the pressure fluid alone, or the admission of the pressure fluid alternating with vacuum where the pump chamber is to operate with a negative suction head.

The diaphragm pumps, while stress-compensated in that they avoid high diaphragm stresses during the pumping stroke, are somewhat sluggish especially where a negative suction lift with the aforementioned vacuum assist is involved. Consequently, their capacity is relatively limited due to the time-consuming character of the operating cycle which in the case of negative suction lift operation, and with air as the pressure medium, comprises:

- a. admission, build-up, and maintaining of pressure in the actuating chamber to effect the pumping stroke,
- b. venting the air pressure chamber to the atmosphere at the end of the pumping stroke,
- c. admission, build-up, and maintaining of vacuum instead of air pressure in the actuating chamber, to effect the pump-filling stroke, and
- d. again venting the chamber to the atmosphere in preparation for the next pumping cycle.

The conventional diaphragm pumps operating in this manner are therefore relatively sluggish especially in the handling of sludges of higher densities and/or viscosities, yet they provide a relatively smooth and cushioned operating cycle due to the gradual transition from one stroke to the next, a characteristic that is

lacking in the mechanically actuated class of diaphragm pumps.

Diaphragm pumps of the class that are wholly mechanically or positively actuated, although requiring only a power supply for their operation, suffer from the disadvantage that the diaphragm due to its positive mechanical connection to a reciprocating drive, is subject to a combination of high shearing, bending, and tension stresses in the operation of the pumping cycle, especially so when operating against a high pumping head. These stresses are aggravated by the uncushioned reversal of the forces affecting the diaphragm at the end of the respective strokes of the pumping cycle. This in turn limits diaphragm life, as well as discharge head capability. Such stresses then lead to shutdowns and the need for replacing the diaphragm when destruction thereof is imminent or has occurred.

Thus, maximum stresses in the diaphragm occur during the pumping stroke when the actuating rod acting like a punch upon the central portion of the diaphragm, must push against the full pumping head which may be in the order of, say, 100 ft. By comparison, the average diaphragm stresses developing during the return — or pump filling stroke with negative suction lift are much smaller, namely a fraction of the 34 ft. maximum lift as determined by the atmospheric pressure. A practical average suction lift frequently required may be in the order of 10 to 12 ft., as compared with a pumping head that may be, say, 10 times that much.

Another drawback of the mechanically actuated diaphragm pump lies in the fact that the diaphragm bending stresses are aggravated due to the abrupt stress reversal occurring at the end of each stroke, and furthermore due to mass action stresses, if the pumping speed should be increased.

In view of the foregoing criteria of conventional machines, it is a general object to provide an improved diaphragm pump that is free from the essential drawback of the aforementioned two groups of diaphragm pumps.

Consequently it is among the more specific objects to provide a fluid pressure-actuated diaphragm pump which avoids the high diaphragm stresses of the mechanically actuated diaphragm pump;

which is capable of substantial capacity increase through higher speeds at minimum wear and tear on the diaphragm;

which overcomes the sluggishness and capacity limitations of the fluid pressure-actuated diaphragm pump, while maintaining the cushioning effects in the operating cycle, whereby excessive diaphragm stresses are avoided even at increased pumping speeds;

which is operable at a negative suction head higher than was heretofore practically feasible, to an extent approaching the atmospheric limit;

which has simple controls for the adjustment of pumping speed, capacity, and stroke while the pump is in operation;

which is operable without the use of the conventional vacuum assist, against any desired negative suction head within the atmospheric limit;

and which is economical to operate, requiring only a supply of fluid pressure medium.

Another object is to provide means for converting a fluid pressure-actuated diaphragm pump arranged for operation with positive — or gravity suction head, into

one capable of negative suction lift operation, while utilizing a pressure fluid supply instead of vacuum.

Another object is to provide means for substantially increasing the capacity of fluid pressure-actuated diaphragm pumps irrespective of whether or not they operate with gravity — or negative suction head.

Still another object is to provide a diaphragm pump of great versatility, applicable to a large spectrum of operating conditions and requirements relative to capacity, pumping discharge head, and suction head.

To attain the foregoing objectives, the invention provides a fluid pressure-actuated diaphragm pump provided with a fluid pressure-actuated auxiliary actuating device connected to the diaphragm, and operable in such a manner that the fluid pressure applied to the auxiliary device will impart to the diaphragm a positive suction lift stroke, whereupon fluid pressure applied to the diaphragm will effect the pump delivery stroke. The fluid pressure effecting the suction stroke, and the fluid pressure effecting the pump delivery stroke, are applied in alternation automatically through a control system governed by the reciprocating movement of the diaphragm.

In one embodiment illustrating the invention, the auxiliary actuating device is in the form of an actuating cylinder unit mounted upon the pump housing, with the piston rod coaxially connected to the diaphragm.

In another embodiment, the auxiliary actuating device comprises a second diaphragm concentric with the pump diaphragm, and a force-transmitting rod interconnecting the centers of the two diaphragms.

The operating air pressure for effecting both the suction stroke and the delivery stroke may be derived from a single source of supply, although the pressures admitted to the actuating device and the pumping chamber respectively, may be individually controlled. Thus it is a highly practical feature that the pumping speed is adjustable simply by controlling the operating pressures without stopping the operation of the pump.

Other features lie in the arrangement and details of the system that controls the pumping cycle, and maintains continuous pump operation.

Other features are found in the structural combination of the pump housing with an actuating cylinder unit.

Other features lie in the combination of the pump housing with the actuating cylinder, and with the control system.

Other features and advantages will hereinafter appear.

As this invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is illustrative and not restrictive. The scope of the invention is defined by the appended claims rather than by the description preceding them, and all embodiments which fall within the meaning and range of equivalency of the claims are therefore intended to be embraced by those claims.

FIG. 1 is a vertical sectional view of the diaphragm pump according to one embodiment of this invention, showing the mounting of the auxiliary actuating device in the form of an actuating cylinder unit, with the piston rod extending into the pump housing in sealing relationship therewith.

FIG. 2 is a cross-sectional view taken on line 2—2 of FIG. 1.

FIG. 3 is a top view taken on line 3—3 in FIG. 1.

FIG. 4 is an enlarged detail view taken from FIG. 1, clearly showing the sealing means for the piston rod.

FIG. 5 is a schematic view of the diaphragm pump of FIG. 1, showing one embodiment of a control system of fluid actuated valves for maintaining the pumping cycle controlled by the movement of the diaphragm, in condition for the pump delivery.

FIG. 6 is a schematic view showing the control system of FIG. 5 conditioned for the pump filling or return stroke of the pumping cycle.

FIG. 7 is a schematic view of another embodiment of the pump operating control system employing solenoid-actuated control valves, conditioned for the pump delivery phase.

FIG. 8 is a schematic view showing the control system of FIG. 7, conditioned for the pump filling return stroke of the pumping cycle.

FIG. 9 is a detail view showing another embodiment of the solenoid actuated valve of FIGS. 7 & 8.

FIG. 10 shows schematically the diaphragm pump in another embodiment of the invention, using an actuating diaphragm instead of the cylinder unit.

FIGS. 11 and 12 are schematic views similar to FIGS. 5 and 6, showing another embodiment of the control system, with the pumping cycle controlled by the movement of the diaphragm.

FIGS. 13 and 14 show a control system similar to FIGS. 11 and 12, actuated by the movement of the diaphragm, although functionally limited to gravity pump intake operation.

The diaphragm pump of this invention, as exemplified in the embodiment of FIG. 1, comprises as main component sections a pump housing 10 having inlet and outlet connections 11 and 12 at the bottom provided with inlet and outlet check valves 11a and 12a respectively (see FIGS. 5 and 6), an actuating cylinder unit 13 mounted upon the top of the housing coaxial therewith, and a control box 14 mounted atop the actuating cylinder unit, which control box is part of a control system for maintaining the pumping cycle. The control system itself is shown in the schematic FIGS. 5 and 6.

The pump housing contains a pump diaphragm 15 of suitable flexible material, which diaphragm is peripherally clamped between a lower housing section 16 and an upper housing section 17 as indicated by the bolt connections 18. The diaphragm thus divides the housing into a lower pumping chamber 19 communicating with said pump inlet and pump outlet connections, and an upper pump actuating chamber 20. This chamber 20 has a pipe connection 21 whereby a fluid pressure medium is admitted to execute the pumping stroke, and through which the chamber is vented during the return stroke of the pumping cycle, all as will be furthermore described below in connection with the control system of FIGS. 5 & 6.

The diaphragm has a central opening 22 closed by a pair of circular clamping plates 23 & 24 tightly engaging the inner beaded edge 25 of the diaphragm. The pumping chamber is shown to be provided with protective or abrasion resistant rubber — or composition lining 26 covering the lower housing section, and a coating of similar material 26a on the exposed surfaces of the lower clamping plate 23.

The clamping plates are positioned relative to each other by locating pins 27, and are held together by screw bolts 28a.

The screw bolts are threaded into the lower clamping plate 23 with their heads 28a located adjacent to and preferably countersunk in the upper clamping plate, and preferably countersunk therein as shown in FIG. 1. The upper clamping plate is rigidly although detachably connected to an actuating rod 29 by means of a screw bolt 28b threaded into the lower end of the rod coaxial therewith. In this way, all fastening bolts in the clamping plate assembly are protected from contact with the contents of the pumping chamber, thus allowing the lower clamping plate to present an unbroken surface "S" which may be coated with a protective material similar to the lining of pump chamber. This coating provides a cushion when contacting the lining of the pump housing at the lower end of the delivery stroke. It is also noted that the coating on the lower clamping plate will remain undisturbed in case the clamping plates are to be dismantled.

The piston rod 29 rigidly connected to the clamping plate assembly, extends upwardly through an opening 30 in the upper housing section, and into the actuating cylinder unit 13 concentric with the housing.

The actuating cylinder unit 13 comprises a straight cylindrical member 30a endwise confined between a bottom plate 31 and a top plate 32, all in concentric relationship to one another, as well as concentric with the axis of the pump housing. The parts constituting the cylinder are held together tightly by means of tie rods 32a threaded into the bottom plate 31 (see FIGS. 2 & 3). This cylinder assembly is detachably fixed to the upper housing section 17 by means of screw bolts 33 (see FIG. 2).

This cylinder assembly contains a piston 34 fixedly connected to the upper end of piston rod 29 which extends downwardly from the piston through an opening 36 in the bottom plate, and also through the opening 30 in the pump housing. The lower end of the piston rod is rigidly connected to the clamping plate assembly on the diaphragm, by means of the detachable bolt connection 28b concealed between the two clamping plates, and thus protected against contact with the material being handled by the pump.

A pipe connection 39 through a radial bore 40 in the bottom plate 31 provides communication between the interior of the actuating cylinder and the control system of FIGS. 5 & 6, whereby fluid pressure medium is admitted into the cylinder to execute the pump filling — or return stroke of the pumping cycle, and whereby the cylinder may also be vented to the atmosphere during the pump delivery stroke of the cycle.

A sealing device 41 surrounds the piston rod, connected to underside of bottom plate 31 of the cylinder assembly. The sealing relationship thus established between the piston rod and the pump housing is required in order to contain the fluid pressure in the pump actuating chamber 20 while the cylinder is being vented during the pump delivery stroke, and conversely to contain fluid pressure in the cylinder while the pump actuating chamber is being vented during the pump filling return stroke of the cycle. Referring to the detail of FIG. 4, the sealing device comprises an upwardly directed sealing ring 42 and a downwardly directed sealing ring 43, both being retained in an annular holder 44

bolted to the underside of bottom plate 31 of the cylinder assembly.

An extension — or actuating rod 45 extends upwardly from the upper end of the piston rod, and through an opening 46 in top plate 32 into the control box 14. This actuating rod has mounted thereon a pair of vertically spaced trip members or stop members 47 and 48 each of which is adjustable along the rod. The rod may be in the form of a threaded element, and the stop members in the form of nuts.

With these nuts or stop members in properly adjusted position on the rod, it will be shown that at the end of each stroke of the pumping cycle, a respective stop member will actuate a control member 49, thereby causing the control system of FIGS. 5 and 6 to initiate a pump stroke in the opposite direction.

Briefly then, the operating cycle of the pump as governed by the setting of the stop members 47 & 48 moving with the piston rod, is as follows:

Fluid pressure admitted through pipe 39 into actuating the cylinder, will move the piston together with the diaphragm to the upper end position of the pump filling — or pump suction stroke (see FIG. 1), while the actuating chamber 20 is being vented through pipe connection 21. At this point, the lower stop 47 on the extension rod will have thrown the control member 49 in the control box 14 to a position causing the associated control system (FIGS. 5 & 6) to admit fluid pressure through pipe 21 into the pump actuating chamber 20, while allowing the actuating cylinder to be vented through pipe 39. This fluid pressure continues until the diaphragm together with the piston will have reached their lower end position of the pump delivery stroke, indicated in dot-and-dash (See FIG. 1). At this point, the upper stop 48 on the extension rod will have thrown the control member 49 in the control box to the opposite position causing the associated control system (FIGS. 5 & 6) to again admit fluid pressure to the actuating cylinder through pipe 39, while allowing the actuating chamber to be vented through pipe 21, thereby completing the pump operating cycle.

In the control system itself, as implemented according to the embodiment of FIGS. 5 and 6, a first control valve 50 communicating with the actuating cylinder through pipe 39, is operable to admit fluid pressure during the pump filling stroke, and to vent the cylinder during the pump delivery stroke. For that purpose, the valve unit 50 has a plug valve member 50a normally urged by a coil spring 50b into the FIG. 5 position whereby a vent connection 50c is established between the actuating cylinder and the atmosphere, as indicated by flow arrows A-1. But when this valve member 50a is moved or depressed against spring pressure from the FIG. 5 to the FIG. 6 position, it will establish a connection 50d for fluid pressure supply to the cylinder as indicated by flow arrows A-2, while a vent connection 50c is closed.

A second similar control valve unit 51 communicating with the pump actuating chamber through pipe 21, is operable to admit fluid pressure through pipe 21 during the pump delivery stroke.

For that purpose, the valve unit 51, has a plug valve member 51a normally urged by coil spring 51b into the FIG. 6 position, whereby a vent connection 51c is established between the actuating chamber 20 and the atmosphere, as indicated by flow arrows A-3. But when this valve member 51a is moved or depressed against

spring pressure into the FIG. 5 position, it will establish a connection 51d for pressure supply to the actuating chamber, as indicated by flow arrows A-4 in FIG. 5.

With the foregoing in mind, the cyclic operation of the control system will be understood by reference to FIGS. 5 and 6, as follows:

The operation of the two control valve units 50 and 51 in properly timed relationship to each other is governed by a pilot valve unit 52 located in the control box atop the actuating cylinder. The reciprocating piston 34 through stops 47 and 48 and control member 49 will shift a plug valve member 53 in the pilot valve unit between the positions of FIG. 5 and FIG. 6 at the end of each piston stroke.

Thus, the pilot valve passes fluid pressure or air pressure (see flow lines A-5) from a source or pipe 54 through pipe 55 to the second control valve unit 51, thereby holding the plug valve member 51a depressed against spring 51b. In this position, the valve member 51a keeps the vent connection 51c closed, while passing fluid pressure or air pressure (see arrows A-4) from a source or pipe 57 and through a pipe 21 into the actuating chamber 20.

At the same time, the FIG. 5 position of the pilot plug valve member 53 will, through a port 58 in the valve member, and through a pipe 59, establish a vent connection 59a with the first control valve unit 50 as indicated by flow arrows A-6. This allows spring 50b to hold the plug valve member 50a biased in the FIG. 5 position, which in turn establishes the vent connection 50c (see arrows A-1) with the actuating cylinder.

Thus, as the piston and diaphragm under fluid pressure from the actuating chamber reach the lower end position of the pump delivery stroke, the upper stop 48 engaging the control member 49 will shift the pilot valve member 53 from the FIG. 5 to the FIG. 6 position. Consequently, fluid pressure or air pressure from pipe 54 will now act through the pilot valve unit and pipe 59 (see flow lines A-7) upon plug valve member 50a, holding the same depressed against the spring 50b, whereby fluid pressure or air pressure is admitted from supply pipe 50d through control valve 50 and transfer pipe 39 into the actuating cylinder, while the vent connection 50c is closed.

At the same time, a port 60 in the pilot valve member will, through pipes 55 and 61 establish a vent connection (see flow lines A-8) to the second control valve unit 51, allowing the spring 51b to move the plug valve member 51a from the FIG. 5 to the FIG. 6 position. This in turn establishes and maintains a vent connection from pipe 51c to the actuating chamber 20 (see flow lines A-3), until the piston and diaphragm under fluid pressure in the cylinder, reach the upper end of the pump filling — or return stroke. At this point, the lower stop 47 engaging the control member 49, will shift the pilot plug valve member back to the FIG. 5 position, thereby initiating the next pumping cycle. The control member 49 may be in the form of a flexible finger or blade, to allow for a slight overrunning of the stops 47 and 48 in the reciprocation of the extension rod.

The supply of fluid — or air pressure through the control system to the pump as shown in FIGS. 5 and 6 is provided from a main supply pipe 62. A branch pipe B-3 leading from the main supply pipe 62 supplies the pilot valve unit 52 with the fluid — or air pressure required for the operation of the control valve units 50

and 51. Branches B-1 and B-2 of the pipe 62 supply the control units 50 and 51 respectively. Advantageously, each of these branches is provided with a constant pressure control valve, which valves are designated as P-1 and P-2 respectively. These constant pressure control valves are of a kind that will hold the pressure on the control valves 50 and 51 constant at an adjustable magnitude, and they may be identified as Norgren Pressure Regulators No. 11-024-0008. In this way, the actuating chamber and the actuating cylinder may be operated at different adjusted pressures. The respective pressures may be raised or lowered, thereby varying the pumping speed or pump delivery rate, without stopping the operation of the pump.

Furthermore, by varying the setting of the stops 47 and 48 on the extension rod, one may vary the length of the pumping stroke, or varying the position of the upper stop alone.

By combining the pressure adjustments with the stroke adjustments in the control system of this invention, a wide range of pump operating requirement can be met.

Hand controlled shut-off valves V-1, V-2, V-3 and V-4 may be provided in the main supply line 62, and in the branches B-1, B-2 and B-3 respectively.

A modification of the pump control system as shown in FIGS. 7 and 8 is functionally equivalent to the system shown in the above described FIGS. 5 and 6 representing the control of the operating cycle. Accordingly, the operating conditions shown in FIG. 7 and FIG. 8 correspond to the conditions shown in FIG. 5 and FIG. 6 respectively.

The difference is due to the fact that the pilot valve unit 52 is replaced by an electrical switch box S, while the air pressure-actuated control valves 50 and 51 are replaced by a pair of solenoid-actuated control valves C-1 and C-2. The switch member M is engaged alternately by stops 47 and 48 in the same manner as the control member 49 in FIG. 5.

Thus, with the switch in the FIG. 8 position, a current from a power supply 63 keeps a solenoid L-1 energized, thereby keeping a pilot plug valve member 64 in a retracted position against the pressure of a spring 65. The pilot valve member thus closes a vent connection 66, while allowing air pressure from pipe 67 acting through passages 68, 69 and 70 to keep a main plug valve member 71 in a position whereby the air pressure is admitted to the actuating cylinder unit through transfer pipe 71a, thus executing the upward pump filling — or suction stroke.

At the same time, the FIG. 8 switch position keeps a solenoid L-2 of valve unit C-2 de-energized, thereby allowing a spring 72 to keep a pilot plug valve member 73 in a position whereby a vent connection 74 is kept open, but passage 75 is closed. Thus, air pressure from pipe 76 acting through passage 77 keeps a main plug valve member 78 in a position whereby a vent connection is established with the pump-actuating chamber 20 by way of vent 79, valve passage 80 and transfer pipe 81.

At the end of the upward pump filling stroke, when the lower stop 47 has thrown the switch member M to the FIG. 7 position, the condition of the solenoids L-1 and L-2 is reversed rendering solenoid L-1 de-energized and solenoid L-2 energized, thereby initiating the downward pump delivery stroke, as indicated by the various flow arrows in FIG. 8.

FIG. 9 represents a modification of the solenoid-actuated control valves of FIGS. 7 and 8, in that solenoids are directly connected to respective main plug valve members of the control valve units.

In another embodiment of the invention according to FIG. 10, the auxiliary actuating device connected to the pump housing and pump diaphragm, comprises an auxiliary pressure-actuated diaphragm instead of the cylinder unit shown in the embodiment of FIG. 1. The pump section 81a itself may remain unchanged, having an actuating chamber 81b and pump delivery chamber 81c on respective sides of the pump diaphragm, and having a connection 81d for admitting air pressure to the actuating chamber during the pump delivery stroke, and for venting the actuating chamber during the pump intake stroke.

Accordingly, a connecting rod 82 connects the clamping plates of the pump diaphragm with similar circular clamping plates 83 and 84 of an auxiliary diaphragm 85. These clamping plates fit over a reduced upper threaded end portion 86 of the connecting rod, secured by a nut 86a. A rod extension 87 of the length E, and preferably of the same diameter as connecting rod 82, has internal thread at its lower end, engaging the threaded upper end of the connecting rod, and tightened against nut 86a as by means of flat faces 88.

The auxiliary diaphragm 85 is contained in an auxiliary diaphragm housing 89, clamped between the lower housing section 90 and the upper housing section 91. The auxiliary diaphragm housing is connected to the pump housing by means of screw bolts or studs 85a arranged internally of the housing. The auxiliary diaphragm thus divides the housing 89 into a lower auxiliary actuating chamber 92, and an upper chamber 93 which is permanently vented at 93a. The lower chamber has a connection 94 communicating with the control system, for supplying air pressure during the suction stroke, and for venting the chamber during the pump delivery stroke.

The connecting rod 82 extending through the bottom 95 of the auxiliary diaphragm housing, is surrounded by a sealing device D similar to the one shown in FIGS. 1 and 4, attached to the underside of bottom 95.

The rod extension 87 is guided in the top portion 96 of the diaphragm housing, and has an upwardly extending coaxial auxiliary rod 97 carrying a pair of vertically spaced adjustable stops or nuts 98 and 99 engaging a control member 100 in control box 101 at the end of each stroke of the pumping cycle, thereby actuating the control system in the manner previously described in connection with FIGS. 1, 5 and 6.

The rod 82 is guided in sealing device D.

Another embodiment of the control system as shown in FIGS. 11 and 12 differs from the system of FIGS. 5 and 6, in that a single main plug valve unit 102 takes the place of the two main control valve units of FIGS. 5 and 6. This single main control valve unit 102 is actuated by an auxiliary — or pilot plug valve unit 103 actuated by the reciprocations of the extension rod.

FIG. 11 illustrates the condition of this control system during the pump suction — or pump filling stroke. Accordingly, the pilot plug valve member 103a is positioned so that air pressure from supply line 104 passing through the pilot valve and pipe 105 has moved the main plug valve member 102a to a position where air pressure from supply line 106 passing through the main valve and through pipe 107 acts upon the piston 34

moving the same upwardly until it in turn through the extension rod 45 moves the pilot plug valve member to the FIG. 12 position. During this pump suction stroke the pilot valve unit has an open vent connection 108, while the main valve unit has an open vent connection 109.

FIG. 12 illustrates the condition of this control system during the pumping — or pump delivery stroke. Accordingly, the pilot plug valve member 103a is positioned so that air pressure from supply line 104 passing through the pilot valve and pipe 110 has moved the main plug valve member 102a to a position where air pressure from supply line 106 passing through the main valve and through pipe 111 acts upon the pump diaphragm 15 moving the same downwardly against the pump delivery head, until the extension rod 45 again reverses the position of the pilot plug valve member. During this pump delivery stroke the pilot valve unit has an open vent connection 112, while the main valve unit has an open vent connection 113.

In a comparison of the embodiments of the control systems of FIGS. 5 and 11 respectively, it may be seen that the springs 50b and 51b in the twin control valve arrangement of FIG. 5 produce a relatively snappier or more instantaneous movement of the respective plug valve members 50a and 51a, over the single control valve arrangement in FIG. 11, whereas the single control valve 102 may have the advantage of greater simplicity and lower cost.

The two identical air pressure actuated control valve units 50 and 51 in the FIGS. 5 and 6 embodiment are available from Mac Valves Inc., Detroit, Michigan, Model 4444. The pilot valve unit 52 in the same embodiment is available from In-Val-Co., Tulsa, Oklahoma, Model No. 416EF1.

The two identical solenoid-actuated control valve units C-1 and C-2 in the FIGS. 7 and 8 embodiment, are available from Mac Valves Inc., Detroit, Michigan, Model 4624C.

The single air-actuated control valve 10 in the FIGS. 11 and 12 embodiment is available from Mac Valves Inc. Detroit, Michigan, Model 2733, while the pilot valve unit 103 is Model 1807-1-07 from the same source.

The feature of controlling the valve system and thereby the pumping cycle, from the movement of the diaphragm itself, is further illustrated in FIGS. 13 and 14 which differ from respective FIGS. 11 and 12 in that the pumping cycle operates with the pump located for gravity feed supply to the pumping chamber.

As represented in FIGS. 13 and 14, this pumping cycle operates as follows:

In this embodiment, the pump body or housing 114 is divided by a diaphragm 115 into a pumping chamber 116 and a pump actuating chamber 117. The central opening 118 of the diaphragm is closed by a pair of circular clamping plates 118a and 118b such as described above in connection with FIG. 1. A rod 119 is fixed to, and extending rigidly from the center of the clamping plates through the actuating chamber 117, is guided in a pair of bushings 120 and 121 mounted in a guide member 122 having a flange connection 123 with the pump body. The lower bushing 121 contains a seal 121a surrounding the rod, and effective to contain air pressure supplied to the actuating chamber 117.

A pilot valve unit 124 is identical to the one in FIGS. 11 and 12, and is similarly actuated by an extension rod

125, to operate a control valve unit 126. Accordingly, at the end of a downward pumping stroke, with the pilot valve member 127 in the FIG. 13 position, air pressure from supply line 128 and branch line 129, will have reached the left hand end of the control valve 126 via a passage 130 in the pilot valve and a transfer pipe connection 131, and will have moved the control plug valve member 132 to its right hand end position. In this FIG. 13 condition of the two plug valve members, the actuating chamber 117 is being vented through transfer pipe 133 and passage 134 in the control valve unit, thus allowing gravity pump feed to fill the pumping chamber 116, moving the diaphragm to its upper end position (see arrow B-1).

At the end of this upward pump filling stroke, the stop member 135 through bridge member 136 will move the pilot plug valve member 127 to the FIG. 14 upper end position, allowing fluid pressure from branch line 129 via passage 137 in the pilot valve and transfer pipe 133a to move the control plug valve member 132 to its left hand end position. In this FIG. 14 condition of the two plug valve members, fluid pressure from branch supply pipe 129a will reach the pump actuating chamber 117 via passage 138 in the control valve unit and transfer pipe 133, initiating the downward pump delivery stroke of the diaphragm (see arrow B-2). At the end of this pump delivery stroke, the position of the two plug valve members will be reversed by stop member 135a, thus initiating the next pumping cycle.

In the FIG. 13 condition, it will be seen that the right hand end of the control valve unit 126 is vented via transfer pipe 133a and passage 138 in the pilot valve. In the FIG. 14 condition it will be seen that the left hand end of the pilot valve is vented via transfer pipe 131 and passage 139 in the pilot valve. A constant pressure control valve 140 is shown in branch supply pipe 129a. Hand operated valves 141, 142, and 143 fluid pressure supply pipes are similar to those shown in FIGS. 11 and 12.

I claim:

1. A single acting diaphragm pump system which comprises a pump housing, a diaphragm dividing the housing into a pumping chamber having means for pump intake and pump discharge, and a pump actuating chamber having an opening opposite to, and concentric with the diaphragm, said actuating chamber having a supply- and vent connection for introducing into said pump actuating chamber a fluid pressure medium effective to move the diaphragm to execute the delivery stroke of the pump, as well as for venting said actuating chamber during the return suction stroke of the pump,

a pump actuating self-contained power cylinder unit detachably mounted upon said pump housing concentric with said opening in the pump housing, and comprising a cylindrical body portion, a top plate having a vent opening, a bottom plate provided with a central bottom opening, a piston having a piston rod extending through said bottom opening, said bottom plate having formed therein a flow passage communicating with the interior of the cylinder, for admission of pressure fluid during the pump delivery stroke, and for venting during the pump return suction stroke,

a sealing device connected to said bottom plate, to provide sealing relationship between the piston rod and said bottom plate, a set of external bolt con-

nections between said top plate and said bottom plate, whereby said cylindrical portion is endwise compressed between said plates, and a set of anchoring studs for detachably mounting said power cylinder unit on said pump housing,

and a control system which comprises a first three-way control valve unit having a valve housing provided with communicating connections extending respectively to a supply of said fluid pressure medium, to said auxiliary actuating means and to the atmosphere, and having a first valve member shiftable in said housing, said valve member, said housing and said communicating connections being so constructed and arranged relative to one another that shifting the valve member in one direction will condition the valve unit for admitting said fluid pressure medium to said auxiliary fluid pressure actuated means to execute the pump filling stroke, and shifting of the valve member in the opposite direction will condition the valve unit for venting said auxiliary means during the delivery stroke,

a second three-way control valve unit having a valve housing with communicating connections respectively to a supply of fluid pressure medium and to said actuating chamber and to the atmosphere, and having a second valve member, said valve member and said housing and said communicating connections being so constructed and arranged relative to one another, that shifting the valve member in one direction will condition the valve unit for admitting said fluid pressure medium to said actuating chamber to execute the pumping stroke, and shifting the valve member in the opposite direction will condition the valve unit for venting said actuating chamber during the pump filling stroke,

and a pilot valve cooperatively associated with said first and second control valves, and constructed and arranged so as to be operable to cause the first control valve member to shift in said one direction while causing the second control valve member to shift in said other direction, for executing the delivery stroke, and to cause reversal of the movements of said first and second control valve members for executing the return stroke of the pumping cycle, and an outward extension member for said piston rod provided with means for engaging said pilot control valve in a manner to operate said first and second control valve units, for maintaining the operating cycle of the pump.

2. A single acting diaphragm pump system which comprises a pump housing, a diaphragm dividing the housing into a pumping chamber having means for pump intake and pump discharge, and a pump actuating chamber having an opening opposite to, and concentric with, the diaphragm, said actuating chamber having a supply- and vent connection for introducing into said pump actuating chamber a fluid pressure medium effective to move the diaphragm to execute the delivery stroke of the pump, as well as for venting said actuating chamber during the return suction stroke of the pump,

a pump actuating power cylinder unit detachably mounted upon said pump housing concentric with said opening in the pump housing, and having a piston and a piston rod extending through a central bottom opening of the power cylinder into said pump housing, and connected to the diaphragm,

said power cylinder being in the form of a self-contained unit which comprises a cylindrical body portion, a top plate having a vent opening, a bottom plate through which said piston rod extends, said bottom plate having formed therein a flow passage communicating with the interior of the cylinder for admission of pressure fluid and for venting, a sealing device connected to the underside of said bottom plate, to provide sealing relationship between the piston rod and said bottom plate, thereby sealing the cylinder and the pump housing relative to each other, a set of external bolt connections between said top plate and said bottom plate, whereby said cylindrical portion is endwise sealingly compressed between said plates, with a set of anchoring studs provided for detachably mounting said power cylinder on said pump housing, and a control system for maintaining the pumping cycle, which comprises

a. separate main control valve means movable in one direction to admit pressure fluid into said pump actuating chamber while allowing said power cylinder connection to be vented, and movable in the opposite direction to admit pressure fluid into said power cylinder, while allowing said actuating chamber to be vented,

b. actuator means supported by said cylinder, and cooperatively associated with said piston rod, as well as operatively connected to said separate main control valve means for moving the same in alternate directions incident to the reciprocations of the piston rod,

c. and an outward extension member for said piston rod, provided with means for engaging said associated actuator means in a manner to operate said control valve means, for maintaining the operating cycle of the pump.

3. The pump system according to claim 2, wherein said control system comprises a main plug valve unit having a pressure fluid supply connection, and having a reciprocable main plug valve member, operatively connected to said actuating chamber and to said pressure fluid-actuated auxiliary means, so that said main plug valve member when moved to one end position will allow pressure fluid to pass to said actuating chamber, while a vent connection is established with said auxiliary fluid pressure-actuated means, and that said main plug valve member when moved to the opposite end position will cause the flow through said main plug valve unit to be reversed,

said control system further comprising a pilot plug valve unit having a pressure fluid supply connection, and a reciprocable pilot plug valve member, operatively connected to said main plug valve unit, so that moving the pilot plug valve member by said extension member in one direction will admit fluid pressure through said pilot valve unit to said main plug valve unit, effective to move the main plug valve member in one direction, and that moving the pilot plug valve member by said extension member in the opposite direction will cause said main plug valve member to move in the opposite direction.

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