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Reynolds(10) **Pub. No.: US 2007/0292285 A1**(43) **Pub. Date: Dec. 20, 2007**(54) **DIAPHRAGM PUMP**(76) Inventor: **Steven M. Reynolds**, Lucas, OH (US)

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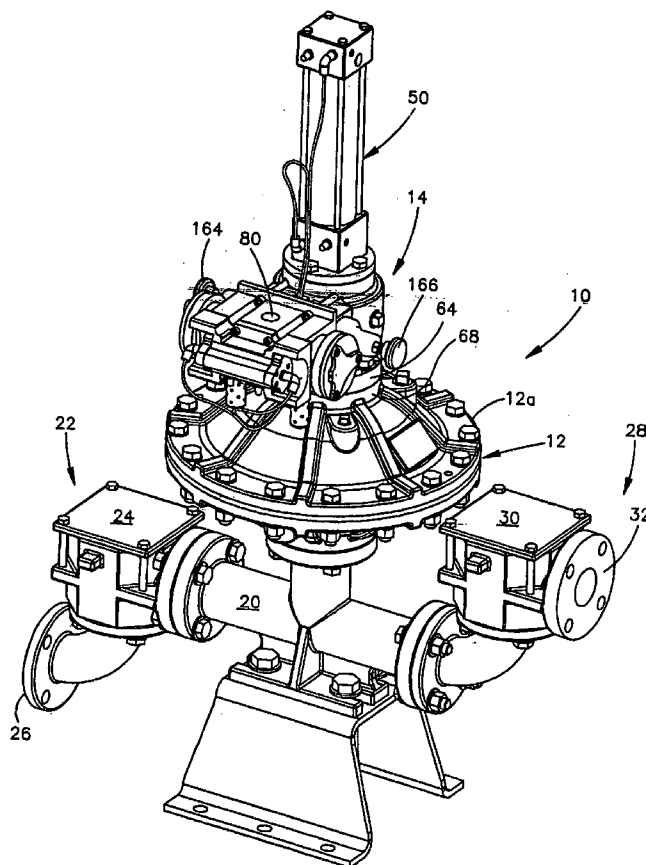
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(52) **U.S. Cl.** **417/397; 417/53**(57) **ABSTRACT**

A diaphragm pump assembly including a control module for controlling the discharge and suction strokes of the diaphragm. The diaphragm pump includes a pump housing defining a pump chamber having a flexible diaphragm supported within the chamber that divides the chamber into a pumping chamber and a pumpage chamber. The pump control module controls the communication of pressurized fluid, i.e., air, to the pumping chamber. A fluid pressure operated actuator is attached to a housing or bracket that is also secured to the diaphragm housing. The actuator includes an actuating rod that extends into operative engagement with the diaphragm. A direction control valve selectively directs fluid pressure to the pumping chamber during a discharge stroke and to a retraction chamber forming part of the actuator during a suction stroke. An intermediate or detent valve controls the direction control valve. First and second end of stroke sensors sense the limits of movement for the actuating rod and apply pressure differential signals to the detent valve to shift an element within the detent valve between two positions. Shifting of the valve element in the detent valve produces attendant changes in state of the direction control valve. A pair of pressure regulators located downstream of the direction control valve and detent valve are used to adjust the fluid pressure applied to the diaphragm during a discharge stroke and the fluid pressure applied to the retraction chamber during a retraction stroke. A port is also provided for optionally feeding pressurized fluid to a discharge stroke chamber forming part of the actuator whenever fluid pressure is applied to the pumping chamber.



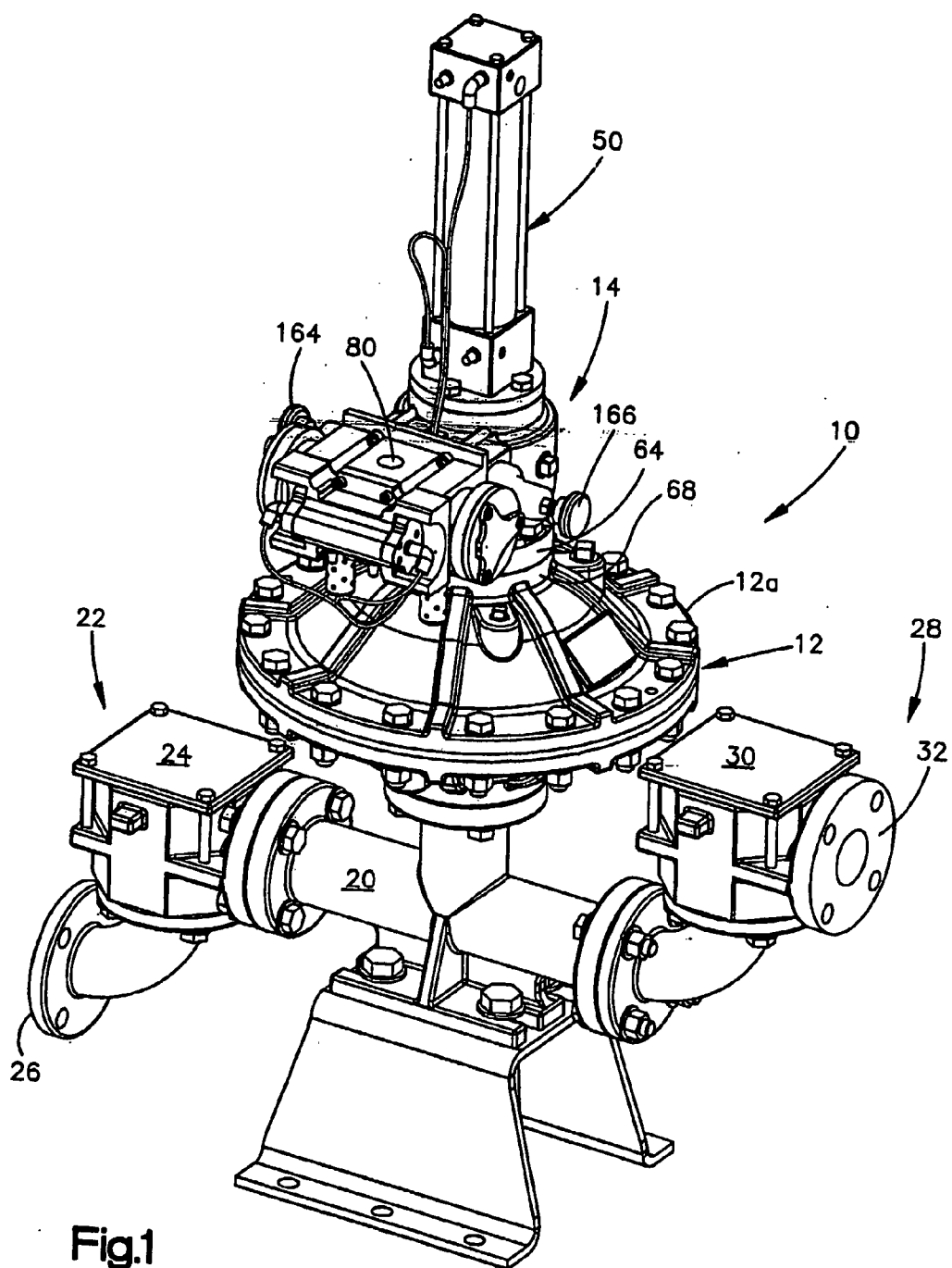
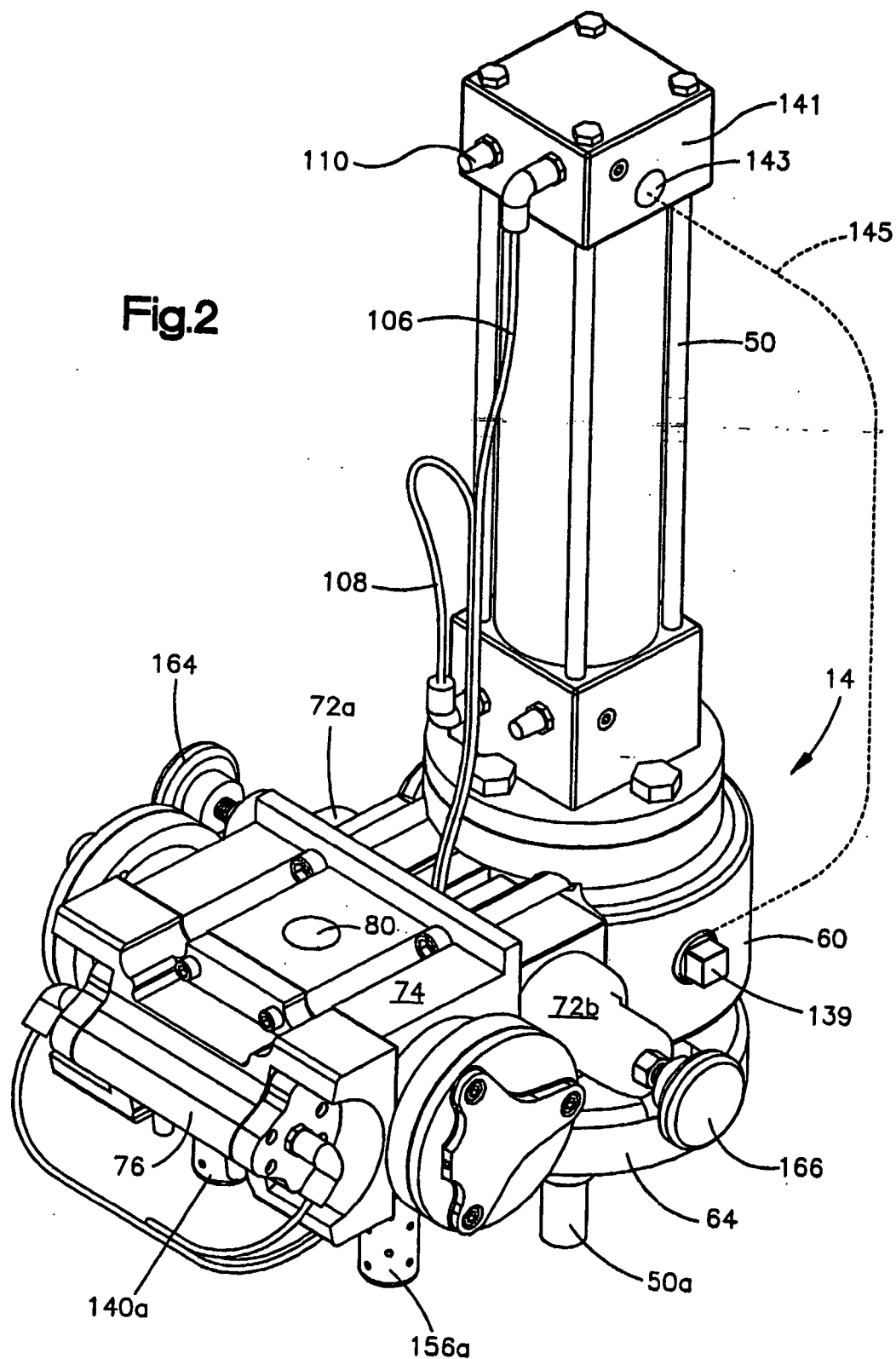
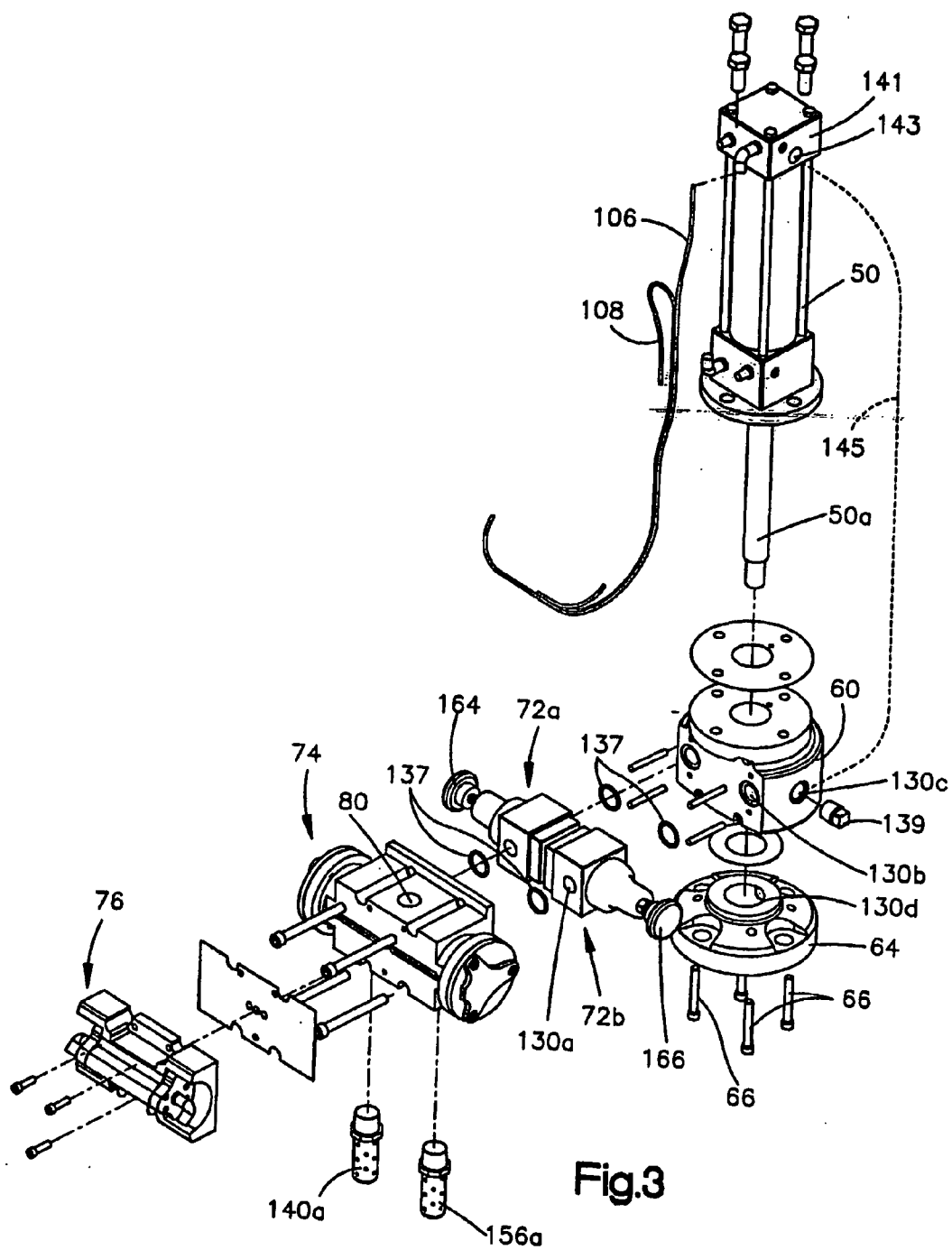
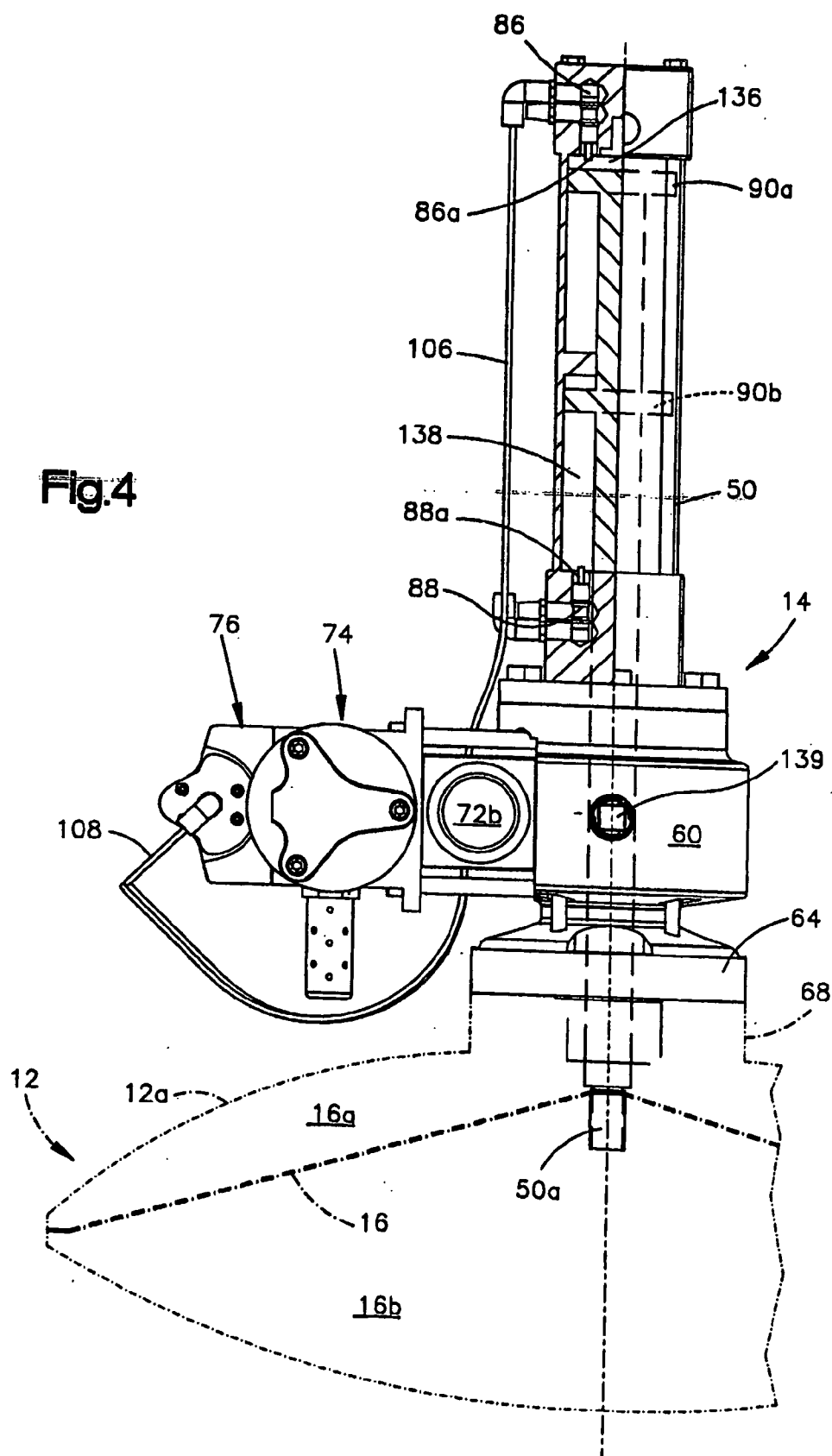
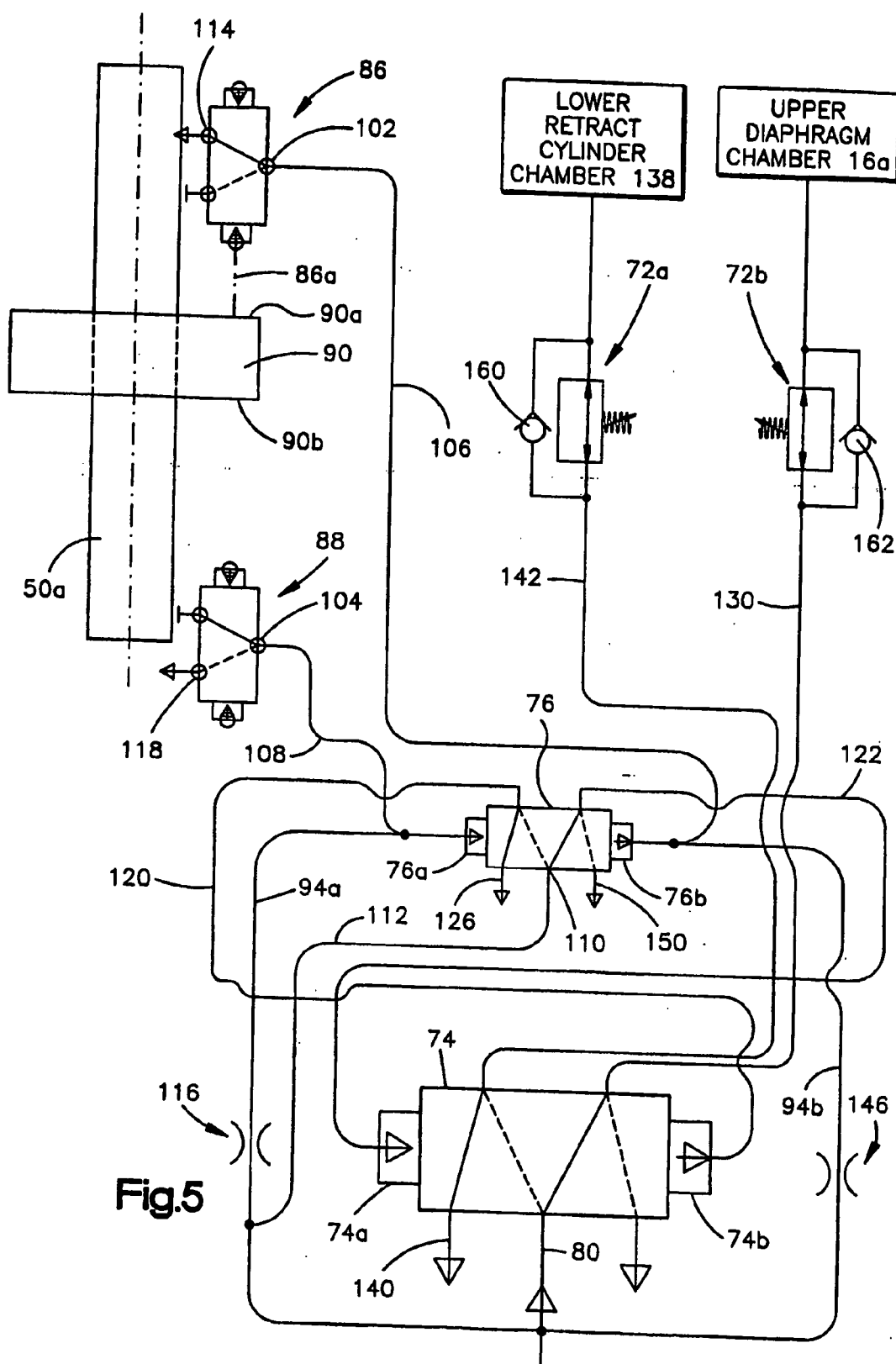


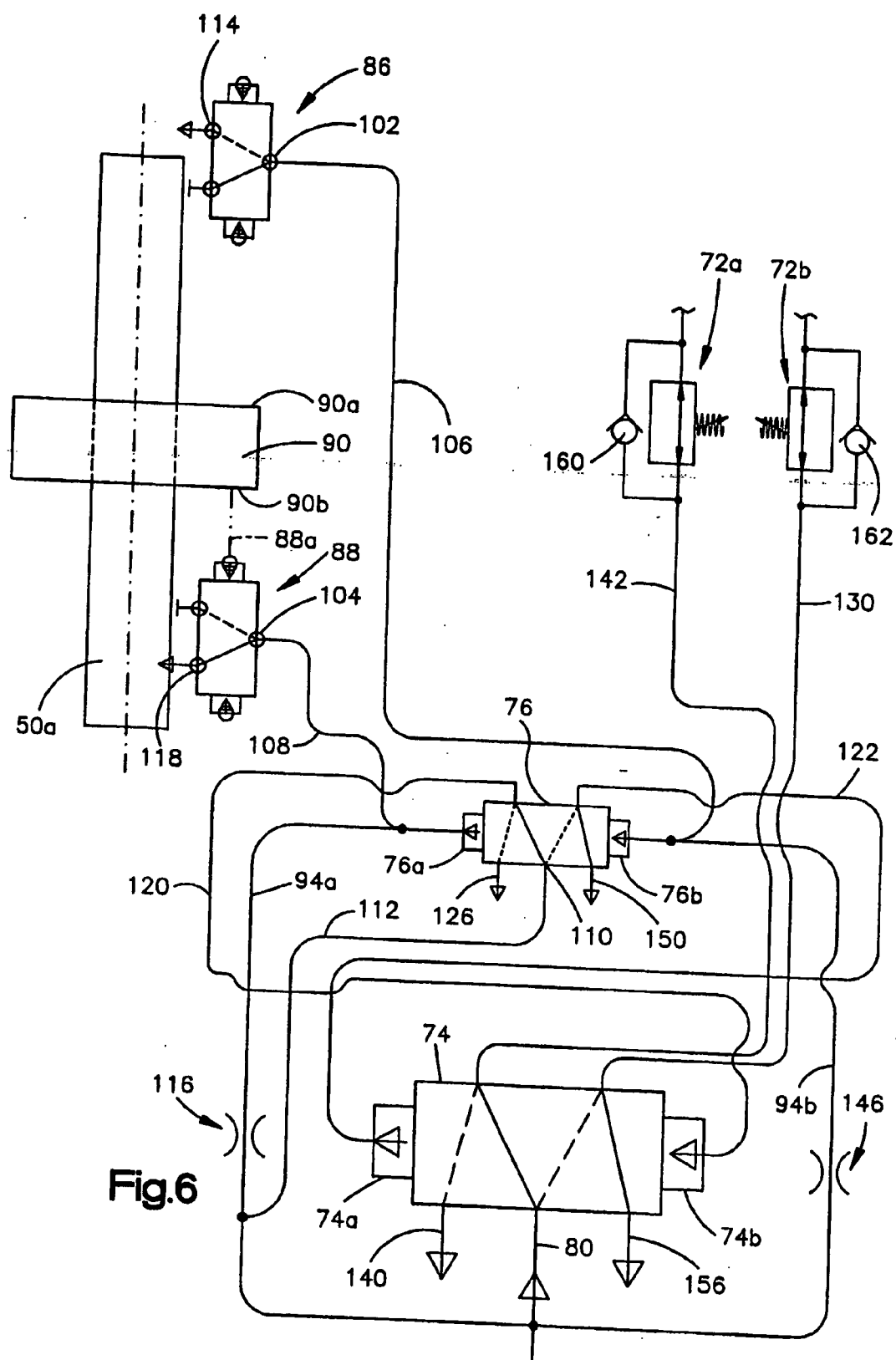
Fig.2











DIAPHRAGM PUMP

TECHNICAL FIELD

[0001] The present invention relates generally to fluid powered diaphragm pumps and, in particular, to a control module for controlling the stroking of a diaphragm forming part of the fluid powered diaphragm pump.

BACKGROUND ART

[0002] Diaphragm pumps are used in a wide variety of applications and are considered to be a positive displacement type pump. Diaphragm pumps are especially useful for pumping fluids that contain solid or semi-solid material which would adversely affect the operation of other types of positive displacement pumps, such as progressive cavity pumps.

[0003] A fluid powered diaphragm pump operates by controlled application of a fluid pressure against a diaphragm mounted within a pump housing. During a pump discharge stroke, the diaphragm exerts pressure upon fluid within the housing causing that fluid to be pumped from a housing outlet. On a suction or return stroke, the diaphragm is withdrawn to allow fluid to enter a housing inlet before a subsequent discharge stroke.

[0004] Prior art fluid powered diaphragm pumps utilize a variety of mechanisms for effecting the discharge and suction strokes. In some prior art pumps, compressed fluid is routed to a diaphragm chamber during the pump discharge stroke which applies a force against the diaphragm causing it to extend and force fluid out the pump discharge. On the suction stroke, the diaphragm chamber is vented and the diaphragm is urged in the opposite direction by either a mechanical spring or a fluid pressure operated cylinder or actuator.

[0005] Examples of prior pump designs are disclosed in U.S. Pat. Nos. 4,621,990 and 4,856,969, both of which are owned by the assignee of the subject application and are hereby incorporated by reference. The '990 patent discloses a diaphragm pump using a spring to store energy during a discharge stroke which is utilized to effect the suction stroke. The '969 patent utilizes a fluid pressure operated cylinder to achieve the suction stroke. In the '969 patent, timers and other electronic controls are disclosed for controlling the suction and discharge strokes for the diaphragm pump.

[0006] Many prior art diaphragm controllers in current use today use fluid logic and associated fluid pressure circuitry to control operation of the pump. Many of these circuits rely on pressure differentials generated in valve control chambers to cause shifting of valve elements. Many of the current diaphragm pump controllers of this type suffer from a "stalling" or "centering" phenomena. When this phenomena occurs, the direction control valve becomes positioned such that it cannot distribute the input power to operate the pump. Manufacturers have attempted to solve this problem using various techniques. These attempts to solve the problem have not been completely successful.

DISCLOSURE OF INVENTION

[0007] The present invention provides a new and improved diaphragm pump and control system and method for controlling a diaphragm pump. In particular, a control

module is disclosed for a diaphragm pump that is adaptable to a wide variety of diaphragm pumps. The control module controls the stroking of the pump and includes pressure regulators for adjusting the rate of stroke and sensors for ensuring that full suction and discharge strokes are executed by the diaphragm pump. The control module is a self-contained unit and can be adapted to both new and old diaphragm pump designs.

[0008] According to the invention, the pump control includes a housing adapted to be mounted to the pump housing of a diaphragm pump and includes a passage for communicating fluid under pressure, i.e., pressurized air to a pumping chamber forming part of the diaphragm pump. A fluid pressure operated actuator is attached to the housing and includes an actuating member, preferably an actuating rod, operatively connected to the diaphragm. First and second end of stroke sensors are provided for sensing predetermined limits of movement for the actuating rod.

[0009] A direction control valve selectively directs fluid under pressure to the pumping chamber during a discharge stroke and to a retraction chamber forming part of the actuator during a suction stroke. A detent valve that is responsive to the end of stroke sensors controls the direction control valve and includes a valve element shiftable between first and second positions. The detent valve is maintained in a given position until it receives a fluid pressure signal generated by one of the end of stroke sensors.

[0010] According to a feature of the invention, first and second pressure regulators are provided for separately adjusting the fluid pressure applied to the pumping chamber and to the retraction chamber during a discharge stroke and suction stroke, respectively.

[0011] Other features of the pump control include a port that is connectable to a chamber forming part of the actuator which, when pressurized, urges the actuating rod in a discharge stroke direction. In the preferred method of operation, this chamber is fed pressurized fluid whenever pressurized fluid is being fed to the pumping chamber.

[0012] According to another feature of the invention, the control module includes replaceable adapter members for adapting the pump control to pump housings of various configurations.

[0013] In the preferred and illustrated embodiment, the direction control valve, intermediate valve, module housing and regulator valves form a unitary subassembly. Fluid passages formed within the components are fluidly interconnected when these valve components are secured together.

[0014] The present invention also discloses a method for operating a diaphragm pump which includes providing an actuator, including an actuating member, i.e., actuator rod operatively coupled to the diaphragm. Fluid pressure is selectively applied to a pumping chamber to cause the diaphragm to move in a discharge direction. Movement of the actuating rod to a predetermined discharge position is sensed. A pressure differential is then generated across a detent control valve to cause it to change position. The operational state of the direction control valve is changed in response to a change in position of the detent valve. Upon a change in state, fluid pressure is then applied to a retraction chamber forming part of the actuator in order to move the

actuating rod in a suction stroke direction. When the actuating rod reaches a predetermined suction stroke position, a second pressure differential is generated which shifts the detent valve to its initial position whereby fluid pressure to the retraction chamber is terminated and fluid pressure is again communicated to the pumping chamber.

[0015] According to a feature of the invention, the pressure regulators, which are used to control the pressure levels sent to the pumping chamber of the diaphragm pump and the retraction chamber of the actuator, are positioned downstream of the fluid pressure applied to the direction control valve. As a result, full line pressure is applied to the direction control valve, thus improving its operation because the pressure differentials that cause shifting of valve elements in both the direction control valve and detent valve are not affected or reduced by the pressure regulators. If the pressure regulators were positioned between the source of air pressure and the control module all fluid pressure applied to the module would be reduced by one or both pressure regulators and reduced performance could result especially at low pressures.

[0016] An object of the invention is to provide an improved control circuit scheme that will allow for the reliable and consistent operation of a device, such as a fluid power diaphragm pump. It is also an object of the present invention to provide a circuit having flexibility in its implementation which allows it to be adapted to a wide variety of fluid pressure operated diaphragm pumps.

[0017] An advantage of the disclosed invention is that it can be installed on existing hardware and utilizes many component parts from the original piece of equipment.

[0018] Additional features of the invention will become apparent and fuller understanding obtained by reading the following detailed description made in connection with the accompanying drawings.

BRIEF DESCRIPTION OF DRAWINGS

[0019] FIG. 1 is a perspective view of a diaphragm pump and control module constructed in accordance with a preferred embodiment of the invention;

[0020] FIG. 2 is a perspective view of the control module constructed in accordance with the preferred embodiment of the invention;

[0021] FIG. 3 is an exploded view of the control module shown in FIG. 2;

[0022] FIG. 4 is a side elevational view, partially in section, of the control module shown attached to a portion of a diaphragm pump that is shown schematically;

[0023] FIG. 5 is a schematic representation of the control circuit forming part of the control module, including a schematic representation of an actuating rod forming part of the control module; and,

[0024] FIG. 6 is another schematic representation of the circuit and fluid pressure control component forming part of the control module.

BEST MODE FOR CARRYING OUT THE INVENTION

[0025] FIG. 1 illustrates a diaphragm pump assembly 10 that includes a diaphragm pump 12 and a control module 14

constructed in accordance with the preferred embodiment of the invention. The pump control module or controller 14 controls reciprocating movement of a diaphragm 16 that forms part of the diaphragm pump 12 and is schematically shown in FIG. 4).

[0026] The diaphragm pump 12 may be conventional and includes a diaphragm housing 12a in which the flexible diaphragm 16 is mounted. As is known and referring also to FIG. 4, the diaphragm 16 divides the diaphragm housing 12a into an upper chamber 16a and a lower chamber 16b (shown only in FIG. 4). The lower chamber 16b is connected to a base Tee 20 (FIG. 1) through which the pumpage or effluent flows. The inlet to the pump 12, indicated generally by the reference character 22 is defined at least in part by a conventional check valve 24 which operates to allow the pumpage to flow, substantially unrestricted, from an inlet flange 26 to the base Tee 20.

[0027] A pump discharge indicated generally by the reference character 28 is defined in part by a discharge check valve 30 which permits substantially unrestricted fluid flow from the base Tee 20 to a discharge flange 32 but inhibits reverse fluid flow from the discharge flange 32 to the base Tee 20.

[0028] The pump control module 14 effects vertical, reciprocating movement (as viewed in FIG. 1) in the diaphragm 16 located within the diaphragm housing 12a (shown in FIG. 4). As the diaphragm 16 is moved upwardly in what is usually termed a "suction stroke," material to be pumped is drawn into the base Tee 20 and lower chamber 16b of the diaphragm pump via the inlet check valve 24. Pumped material at the discharge flange 32 is inhibited from being drawn into the base Tee 20 by virtue of the discharge check valve 30. Following the suction stroke of the diaphragm, the control module or controller 14 effects downward movement of the diaphragm 16 which is usually termed a "discharge stroke". The downward movement of the diaphragm 16 forces pumpage material from the lower diaphragm chamber 16b into the base Tee 20 and out through the discharge check valve 30. The material being pumped is inhibited from flowing to the inlet flange 26 by virtue of the inlet check valve 24. As should now be understood, and which is also conventional, the reciprocating movement of the diaphragm 16 causes pumpage material to be conveyed under pressure from the inlet flange 26 to the discharge flange 32.

[0029] The reciprocation or "stroking" of the diaphragm 16 is controlled by the pump control module 14. Referring to FIGS. 1-4, the pump control module 14, in the preferred embodiment, is fluid pressure operated and in the illustrated embodiment, is operated by air pressure,

[0030] Referring in particular to FIGS. 2 and 3, the control module 14 includes a fluid pressure operated actuator or cylinder 50 that includes an actuating rod 50a that is connected to the diaphragm 16 located within the pump's diaphragm housing 12a (the connection is schematically shown in FIG. 4). As is conventional, the primary purpose of the cylinder 50 and associated actuating rod 50a is to retract the diaphragm 16, i.e., move it to its upper position as viewed in FIG. 4. In short, the primary purpose of the cylinder 50 is to effect the "suction stroke" of the pump.

[0031] Referring in particular to FIG. 3, the cylinder 50 is secured to an intermediate housing or bracket 60. An adapter

64 is secured to the underside of the intermediate bracket **60** by a plurality of bolts **66**. The adapter **64** which is flange-like in construction is bolted to a pump flange **68** forming part of the diaphragm housing **12a** (shown schematically in FIG. 4). As seen in FIG. 4, the actuating rod **50a** extends through the intermediate bracket **60** and adapter **64** and is connected to a central portion of the diaphragm **16**. The lower end of the actuating rod **50a** may include a threaded segment adapted to threadedly engage the center of the diaphragm **16**.

[0032] The intermediate bracket **60** mounts a pair of pressure regulators **72a**, **72b**, a direction control valve **74** and an intermediate valve **76**. As will be explained, the intermediate valve **76** provides a detent or lock function for the direction control valve **74**.

[0033] When the intermediate valve **76**, direction control valve **74**, and pressure regulators **72a**, **72b** are bolted to the intermediate bracket **60**, the necessary fluid communications between the components are established by porting and passages formed in the components.

[0034] The fluid pressure circuits that form part of the control module **14** are illustrated schematically in FIGS. 5 and 6. Referring to FIGS. 1-6, a source of air pressure which provides the motive force for the diaphragm **16** and the cylinder **50** is connected to an inlet port **80** forming part of the direction control valve **74**. Referring to FIGS. 4 and 5, in the preferred and illustrated embodiment, the cylinder **50** includes upper and lower end-of-stroke sensors **86**, **88** which directly or indirectly sense the extreme upper and lower positions of the actuating rod **50a** that forms part of the cylinder **50**. When the actuating rod **50a** reaches its upper extreme of travel (as viewed in FIG. 4) an upper piston surface **90a** actuates a valve actuating pin **86a** forming part of the end-of-stroke sensor **86**.

[0035] In the construction shown in FIG. 4, the illustrated cylinder **50** includes upper and lower piston heads **90a**, **90b** which are attached to or form part of the actuating rod **50a**. Cylinders having alternate constructions may be used with the present invention and this invention should not be limited to the construction of the cylinder **50** shown in FIG. 4. In particular, a cylinder may be used that includes only a single piston **90**, as shown in FIGS. 5 and 6. In this type of cylinder, an upper surface **90a** of the single piston **90**, contacts and operates the actuating pin **86a** when the actuating rod **50a** reaches its uppermost position.

[0036] In the preferred embodiment, the end-of-stroke sensors **86**, **88** are normally closed, pneumatic valves. The upward movement of the actuating pin **86a** shifts a valve element within the normally closed end-of-stroke sensor **86** to establish the fluid communication shown schematically in FIG. 5 and allow fluid flow through the valve. In its unactuated position, the end-of-stroke sensor **86** blocks flow through the valve.

[0037] As seen in FIG. 5, the source of fluid pressure (in this case air pressure) is communicated to the inlet port **80** that forms part of the direction control valve **74**. It is also communicated to pilot pressure chambers **76a**, **76b** of the intermediate valve **76** via supply passages **94a**, **94b**. Supply pressure is also communicated to input ports **102**, **104** forming part of end-of-stroke sensors **86**, **88**, respectively by branch supply passages **106**, **108**. Finally, supply pressure is also supplied to a supply port **110** of the intermediate valve

76 by a branch supply conduit **112**. The direction control valve **74** is also pilot pressure operated and includes opposed pilot pressure chambers **74a**, **74b**. As is conventional, a valve element within the direction control valve **74** shifts in response to differential pressures established in the pilot pressure chambers **74a**, **74b**. Similarly, a valve element forming part of the intermediate valve **76** is also shifted in response to differential pressures in the pilot pressure chambers **76a**, **76b**.

[0038] The operation of the control module **14** will now be explained. FIG. 5 illustrates the states of the control system components and valves when the actuating rod **50a** reaches its uppermost position (as viewed in FIG. 5) and has actuated the end-of-stroke sensor **86**. As the actuating rod **50a** reaches the end of its suction stroke (the upper extreme of movement for the actuating rod), the end-of-stroke sensor pin **86a** is operated by the piston surface **90a** or the upper piston **90a**-FIG. 4) and moves a valve element within the end-of-stroke sensor **86** from its normally closed position to an open position at which the input port **102** is communicated with an atmospheric port **114**. This immediately vents the supply line **106** to atmosphere thereby venting the pilot pressure chamber **76b** of the intermediate valve **76**. The supply line **94b** that feeds both the pilot pressure chamber **76b** and the supply port **102** of the end-of-stroke sensor **86** includes an orifice **146** sized to restrict the flow of air to the pilot pressure chamber **76b** such that the rate at which the air is vented via the end of stroke sensor **86** is greater than the rate of replenishment air. As a result, a pressure substantially less than source pressure is created in the pilot pressure chamber **76b**.

[0039] The left pilot pressure chamber **76a** (as viewed in FIG. 5) is maintained at source pressure via the branch supply line **94a** and the closed position of the lower end-of-stroke sensor **88**. In the closed position, supply pressure at the input port **104** is blocked from atmospheric port **118** forming part of the lower end-of-stroke sensor **88**. This differential pressure established by the pilot pressure chambers **76a**, **76b** across the valve element of the intermediate valve **76** causes it to shift rightwardly and establish the fluid communication shown in FIG. 5, which as will be explained causes a shift in the direction control valve **74**.

[0040] In particular, a pilot pressure chamber signal passage **120** which is connected to the right pilot pressure chamber **74b** of the directional control valve **74** is vented to an atmospheric port **126** of the intermediate valve **76**. A pilot pressure chamber signal passage **122** which is connected to the left pilot pressure chamber **74a** is communicated to source pressure via the intermediate valve **76** and branch supply passage **112**. As a consequence, a differential pressure is established across the main control element of the direction control valve **74** causing it to shift rightwardly (as viewed in FIG. 5) and establish the fluid pressure communications necessary to execute a discharge stroke in the diaphragm pump **12**.

[0041] As seen in FIG. 5, when the direction control valve **74** is shifted to the right, source pressure at the supply port **80** is connected to a pressure conduit **130**. The pressure conduit or passage **130** communicates with the upper chamber **16a**. When the upper chamber **16a** is pressurized, the diaphragm **16** is urged downwardly and causes pumpage in the lower chamber **16b** and base Tee **20** to be driven out the

pump discharge 32 (see FIG. 1). For some applications, the conduit 130 may also be connected to an upper chamber 136 of the cylinder 50 (shown in FIG. 4) in order to create a downward force on the actuating rod 50a which is also applied to the diaphragm 16.

[0042] The passage 130 (which is shown schematically in FIG. 5) is defined by passages and other structures formed in the control module 14. In particular, the passage 130 is defined in part by a passage 130a formed in the pressure regulator 72b and a passage 130b defined by the intermediate bracket 60. A cross drilled passage 130c communicates the passage segment 130b with a central region 130d defined by the adapter 64. The region 130d defines an opening through which the actuating rod 50a extends to connect with the center of the diaphragm 16.

[0043] The passages 130a, 130b, 130c are cross connected when control module 14 is assembled. O-ring seals 137 are used to seal the passage connections when the direction control valve 74, the pressure regulators 72a, 72b and intermediate bracket 60 are bolted together. The region 130d communicates with the upper chamber 16a and, thus, air delivered to the passages 130a, 130b, 130c and 130d provide air pressure to the upper diaphragm chamber 16a during a discharge stroke.

[0044] Similarly, the passage 142 (shown schematically in FIGS. 5 and 6) is defined by passage segments defined by the regulator valve 72 and intermediate bracket 60. A passage (not shown) formed in the intermediate bracket 60 is in fluid communication with the lower chamber 138 of the cylinder 50.

[0045] The cross drill passage 130c is normally sealed by a removable plug 139. For those applications, where the upper chamber 136 of the cylinder 50 is to be pressurized during a discharge stroke, the cross drill passage 130c is connected to the upper cylinder chamber 136. In particular, the plug 139 is removed and replaced by a fluid pressure fitting. An upper cylinder head 141 of the cylinder 50 includes a port 143 that communicates with the upper chamber 136. The port 143 is normally open to atmosphere if the upper chamber 136 is not to be pressurized. To achieve pressurization of the upper chamber 136 during a discharge stroke, a conduit shown schematically as 145 is connected between cross drill passage 130c and the port 143.

[0046] Concurrently with the pressurization of the upper diaphragm chamber 16a, a lower piston chamber 138 of the cylinder 50 (shown in FIG. 3), is vented to an atmosphere port 140 on the direction control valve 74 via pressure conduit 142. The depressurization of the lower cylinder chamber 138 eliminates the retract force exerted on the actuating rod 50a and allows the diaphragm 16 to move downwardly with a force determined by the air pressure in the upper chamber 16a (and the upper cylinder chamber 136 if pressurized) and effect a discharge stroke.

[0047] As the actuating rod 50a moves downwardly, the normally closed valve element forming part of the upper end-of-stroke sensor 86 returns to its normally closed position, thus repressurizing the right pilot pressure chamber 76a of the intermediate valve 76. Since both pilot pressure chambers 76a, 76b are now at source pressure, i.e., balanced, the valve element remains in position shown in FIG. 5.

[0048] Turning now to FIG. 6, as the actuating rod 50a reaches the end of its discharge stroke, the lower piston surface 90b (or lower piston surface in a single piston cylinder 90b) actuates the lower end-of-stroke sensor 88 and moves its associated valve element from its normally closed position to an open position at which its input port 104 is communicated to atmosphere via port 118. The input port 104 of the end-of-stroke sensor 88 is connected to the pressure supply conduit 94a via branch passage 108; the supply passage 94a also communicates source pressure to the left pilot pressure chamber 76 of the intermediate valve 76. The supply conduit 94a includes an orifice 116 designed to limit the rate at which air pressure can flow to the pilot pressure chamber 76a. Consequently, the venting of the branch passage 94a that is connected to the pilot pressure chamber 76a causes the pressure in the pilot pressure chamber to fall substantially below source pressure thus establishing a differential across the valve element in the intermediate valve 76. This differential shifts the valve element leftwardly (as viewed in FIG. 6) and establishes the fluid pressure communications shown in FIG. 6.

[0049] In particular, the left pilot pressure chamber 74a of the direction valve is vented to atmosphere via the passage 122 which is connected to an atmospheric port 150 on the intermediate valve 76. Concurrently, source pressure is communicated to the right pressure pilot chamber 74b of the direction control valve 74 by means of the supply passage 120 which is connected to the supply conduit 110 via the intermediate valve 76. This establishes a pressure differential across the valve element of the direction control valve 74 causing it to move leftwardly as viewed in FIG. 6 and establish the illustrated communications. In particular, source pressure is communicated to the lower chamber 138 of the cylinder 50 via the supply passage 142. The upper piston chamber 136 and upper diaphragm chamber 16a is vented to atmosphere via supply passage 130 which is connected to an atmospheric port 156 on the direction control valve 74.

[0050] In FIG. 3 mufflers/filters attached to the atmospheric ports 140, 156 of the direction control valve 74 are shown and indicated by the reference characters 140a and 156a, respectively.

[0051] As should be apparent, the actuating rod 50a and hence diaphragm 16 will reciprocate vertically as the direction control valve 74 shifts the application of source pressure to the actuating rod retraction chamber 138 from the upper diaphragm chamber 16a. The end-stroke-sensors 86, 88 ensure that the actuating rod 50a travels to its extremes of movement rather than changing direction when in an intermediate position as is the case with some prior art controllers which switch based on timers. With this disclosed control module apparatus, extremely precise metering of fluid pumped by the pump assembly 12 can be maintained. This is due to the fact that the diaphragm pump 12 is a positive displacement pump and a full stroke of the diaphragm 16 will pump a relatively precise amount of pumpage from the pump inlet 22 to the pump outlet 28.

[0052] In most applications, the air pressure necessary to effect a discharge stroke is substantially greater than the air pressure needed to retract the diaphragm in order to perform a suction stroke. According to a feature of the invention, the discharge stroke pressure is separately adjustable from the

suction stroke pressure. Turning to FIG. 5, as explained above, the supply passage 130 supplies pressure to the upper diaphragm chamber 16a during the discharge stroke (and may also supply pressure to the upper cylinder chamber 136). The adjustable pressure regulator 72b determines the pressure that is delivered to the upper chamber 16a of the diaphragm housing 12a (see FIG. 4) by the supply passage 130.

[0053] As explained above, the supply passage 142 supplies pressure to the lower chamber 138 of the cylinder 50 during the suction stroke in order to move the diaphragm upwardly. The supply line 142 includes a separate, adjustable regulator 72a by which the maximum pressure delivered to the lower chamber 138 is determined.

[0054] The adjustable regulators 72a, 72b can be used to adjust the stroke rate of the pump and, in fact, can be adjusted so that the discharge stroke rate and suction stroke rates are different. For some applications, such as heavy slurries, it may be desirable to have a suction stroke rate that is slower than the discharge stroke rate.

[0055] As also explained above, when the supply passage 130 is supplying air pressure, the passage 142 is used as a vent passage and vice versa. In order to facilitate venting through the passages, respective check valves 160, 162 are used to bypass the pressure regulator 72a, 72b when the passages 142, 130 are venting air pressure, respectively.

[0056] It should be noted here that the illustrated pressure regulators 72a, 72b are adjusted by manually operated adjusters 164, 166. The invention, however, contemplates other types of adjustable pressure regulators, such as remotely controlled, pneumatically and electrically operated pressure regulators.

[0057] As indicated above, the intermediate valve 76 provides a detent or lock function for the directional control valve 74 which inhibits the occurrence of “centering” or “stalling” of the actuator 50. The intermediate valve 76 isolates the direction control valve 74 from partial signals that may be generated by one or both of the end-of-stroke sensors 86, 88. These partial signals may be generated when the piston 90 reaches one of its limits of travel and initially contacts the actuating pin of one of the end of stroke sensors. The initial contact with the actuating pin, causes the intermediate valve to effect a shift in the direction control valve 74. The direction control valve 74 will remain in its shifted position until the opposite end-of-stroke sensor is actuated. Under some operating conditions, pressure fluctuations in the diaphragm chamber may cause the piston to “bounce” and reactuate the end of stroke sensor. With the present invention, this “bounce” will not cause a shift in the direction control valve 74. Only actuation of the opposite end-of-stroke sensor can effect a shift in the directional control valve. As a consequence, the occurrence of “stalling” or “centering” is substantially eliminated.

[0058] Another advantage of the present invention is provided by the position of the pressure regulators in the fluid circuit. As seen best in FIGS. 5 and 6, the directional control valve 74 and the intermediate valve 72 are located upstream of the air pressure regulators 72a, 72b. As a result, the valves 74, 76 are always connected to full line pressure to assure reliable operation. In some control systems where an “upstream” pressure regulator or regulators are used to

adjust the timing of the suction and/or discharge strokes, “stalling” or “centering” may occur. This is due to the reduced operating pressure that results from pressure regulators upstream of the valves that are adjusted to produce lower pressures.

[0059] The disclosed control module can be easily adapted to a variety of diaphragm pumps both new and old. The use of a separate adapter 64 by which the control module 14 is mounted to an existing flange of the diaphragm pump, allows the same control module to be used on diverse diaphragm pumps. Only the adapter 64 needs to be sized and configured for the diaphragm pump flange 68 (see FIG. 4). In addition, differently sized cylinders 50 can be easily fitted to the same intermediate bracket 60 in order to accommodate the stroke distance for a particular pump.

[0060] Although the invention has been described with a certain degree of particularity, it should be understood that those skilled in the art can make various changes to it without departing from the spirit or scope of the invention as hereinafter claimed.

1. A diaphragm pump assembly comprising:

- a) a pump housing that defines a pumping chamber having an inlet to deliver pumpage to the chamber, a flexible diaphragm supported within the chamber to apply pressure to pumpage entering the pumping chamber, and an outlet to discharge pumpage from the pumping chamber;
- b) a pump control module for effecting discharge and suction strokes in the diaphragm, said control module including:
 - i) an intermediate bracket secured to a diaphragm housing forming part of the pump housing;
 - ii) a fluid pressure operated actuator attached to said intermediate bracket and including an actuating rod extending through said intermediate bracket and operatively connected to said diaphragm;
 - iii) a direction control valve for selectively directing fluid pressure to said pumping chamber during a discharge stroke and to a lower chamber forming part of said actuator, during a suction stroke;
 - iv) an intermediate valve for controlling said direction valve;
 - v) a pair of pressure regulators for adjusting the fluid pressure applied to said pumping chamber and to said lower chamber during a discharge stroke and suction stroke, respectively; and
 - vi) a pair of end-of-stroke sensors for sensing the limits of movement for said actuating rod.

2. The diaphragm pump assembly of claim 1, wherein said actuator comprises a fluid pressure operated cylinder.

3. A pump control for controlling the operation of a diaphragm pump, the diaphragm pump including a pump housing supporting a flexible diaphragm that divides the pump housing into a pumping chamber and a pumpage chamber, the pump control comprising:

- a) an intermediate housing adapted to be mounted to said pump housing and including a passage for communicating fluid under pressure to said pumping chamber;

- b) a fluid pressure operated actuator attached to said intermediate housing and including an actuating member operatively connected to said diaphragm;
 - c) first and second end-of-stroke sensors for sensing predetermined limits of movement of said actuating member;
 - d) a direction control valve for selectively directing fluid under pressure to said pumping chamber during a discharge stroke and to a retraction chamber forming part of said actuator, during a suction stroke;
 - e) a detent valve responsive to said end-of-stroke sensors for controlling said direction control valve, said detent valve including a valve element shiftable between first and second positions, said valve element maintaining a given position until a change in a fluid pressure signal caused by one of said end-of-stroke sensors is sensed.
4. The pump control of claim 3 further comprising first and second pressure regulators for adjusting the fluid pressure applied to said pumping chamber and said retract chamber during a discharge stroke and a suction stroke, respectively.
5. The pump control of claim 3 wherein said detent valve inhibits a change in state of said direction control valve until one of said end-of-stroke sensors senses a limit of movement in said actuating member.
6. The pump control of claim 3 further comprising a port, connectable to a chamber forming part of said actuator which when pressurized, urges said actuating member in a discharge stroke direction.
7. The pump control of claim 3 further including a replaceable adapter member for adapting said pump control to pump housings of various configurations.
8. The pump control of claim 3 wherein said directional control valve, intermediate valve, intermediate housing and regulator valves form a unitary sub-assembly which includes fluid passages that are fluidly interconnected when said intermediate valve, directional control valve, intermediate housing and regulator valves are secured together without the need of external fluid conduits.
9. A method for operating a diaphragm pump having a pump housing and a diaphragm located within the pump housing that divides the housing into a pumping chamber and a pumpage chamber, comprising the steps of:
- a) providing an actuator, including an actuating rod, operatively coupled to said diaphragm;
 - b) selectively applying a fluid pressure to said pumping chamber to cause said diaphragm to move in a discharge direction;
 - c) sensing when said actuating rod reaches a predetermined discharge stroke position and generating a pressure differential across a directional control valve to cause it to change position;
 - d) changing the operational state of a directional control valve in response to a change in position of a detent valve in order to terminate the communication of fluid pressure to said pumping chamber;
 - e) applying fluid pressure to a retraction chamber forming part of said actuator in order to move said actuating rod in a suction stroke direction;

- f) sensing when said actuating rod reaches a predetermined suction stroke position and generating a second pressure differential which shifts said detent valve to its first position whereby fluid pressure to said retraction chamber is terminated and fluid pressure is again communicated to said pumping chamber.

10. The method of claim 9 further comprising the step of communicating fluid pressure to a discharge stroke chamber forming part of said actuator when fluid pressure is being communicated to said pumping chamber.

11. The method of claim 10 further comprising the step of separately regulating the fluid pressure applied to said pumping chamber and to said retraction chamber, during the discharge and suction strokes of said actuating rod to thereby separately adjust the rate at which said diaphragm is driven in the discharge stroke and suction stroke directions.

12. A diaphragm pump assembly, comprising:

- a) a pump housing and a flexible diaphragm supported within the housing for dividing the housing into a pumping chamber and a pumpage chamber, said pumpage chamber including a port for receiving pumpage from an inlet conduit during a suction stroke and for discharging pumpage to an outlet conduit during a discharge stroke;
- b) a pump control module for controlling the discharge and suction strokes of said diaphragm, said control module including:
 - i) a fluid pressure operated actuator, including an actuating rod operatively connected to said diaphragm for exerting forces on said diaphragm during said suction stroke;
 - ii) an intermediate member mounting said actuator to said pump housing in an operative position;
 - iii) said intermediate member also mounting a direction control valve and a detent valve;
 - iv) said direction control valve operative to selectively direct fluid under pressure to said pumping chamber during a discharge stroke and to said actuator during a suction stroke;
 - v) said detent valve operative to control said direction valve in response to fluid pressure signals received from end-of-stroke sensors that sense at least two limits of movement of said actuating rod.

13. The diaphragm pump of claim 12 further including a pair of pressure regulators for adjusting the pressure of fluid applied to said pumping chamber and said retraction chamber during the discharge stroke and said suction stroke, respectively.

14. The diaphragm pump of claim 13 wherein said pressure regulators are separately adjustable in order to separately adjust the rate of movement of said diaphragm during said suction and discharge strokes.

15. The diaphragm pump of claim 12 wherein said actuator includes an actuator chamber which when pressurized applies a force to said actuating rod which tends to move said diaphragm in a discharge stroke direction and said pump control module is operative to supply fluid under

pressure to said actuator chamber when pressurized fluid is being supplied to said pumping chamber.

16. The diaphragm pump of claim 12 wherein said detent control valve is responsive to pressure differentials generated by said end-of-stroke valves and said direction control valve is responsive to pressure differentials generated by said detent valve.

17. The diaphragm pump of claim 14 wherein said at least one of said pressure regulators communicates directly with a source of pressurized fluid to which said pump control module is connected to.

18. The diaphragm pump of claim 14 wherein said separately adjustable pressure regulators communicate directly with a source of pressurized fluid for said control module.

19. A diaphragm pump assembly, comprising:

- a) a pump housing that defines a pumping chamber having an inlet to deliver pumpage to the chamber, a flexible diaphragm supported within the chamber to apply pressure to pumpage entering the pumping chamber, and an outlet to discharge pumpage from the pumping chamber;
- b) a pump control module for effecting discharge and suction strokes in the diaphragm, said control module including:

- i) an intermediate bracket secured to a diaphragm housing forming part of the pump housing;

- ii) a pneumatically operated actuator attached to said intermediate bracket and including an actuating rod extending through said intermediate bracket and operatively connected to said diaphragm;

- iii) a direction control valve for selectively directing air pressure to said pumping chamber during a discharge stroke and to a retract chamber forming part of said actuator, during a suction stroke;

- iv) an intermediate valve for controlling said direction valve;

- v) a pair of end-of-stroke sensors for sensing the limits of movement for said actuating rod.

20. The diaphragm pump assembly of claim 19 further comprising a pair of pressure regulators for adjusting the level of air pressure applied to said pumping chamber and to said retract chamber during a discharge stroke and suction stroke, respectively.

21. The apparatus of claim 12 wherein said fluid pressure is air pressure.

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