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(54) Air valve assembly for a double-diaphragm pump

(57) A device is provided for controlling the air supply to and exhaust from an air driven pump having two diaphragm chambers (44, 46), each with a liquid pumping section and an air section separated by a diaphragm (40, 42). The device comprises a chamber (52) containing a pilot valve (60) for actuation in accordance with predetermined positions of the diaphragm (40, 42) and an actuator valve for actuation in accordance with the actuation of the pilot valve (60) to direct pressurised air into a corresponding air section of one of the diaphragm chambers (44, 46). A removable cover (28) for the chamber (52) allows access to the valves.

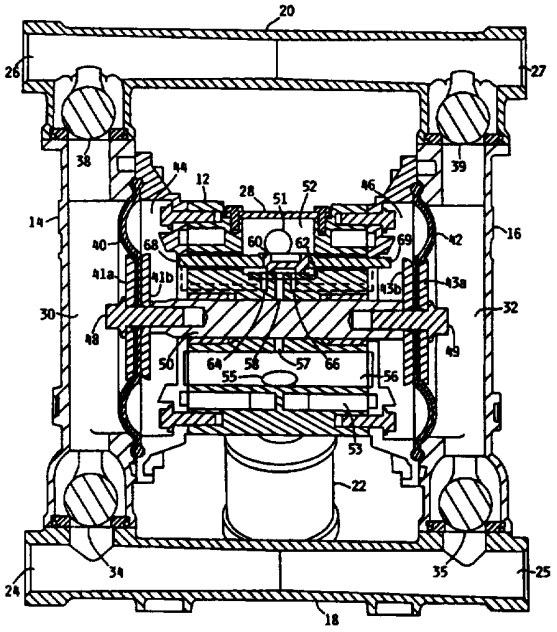

FIG. 3

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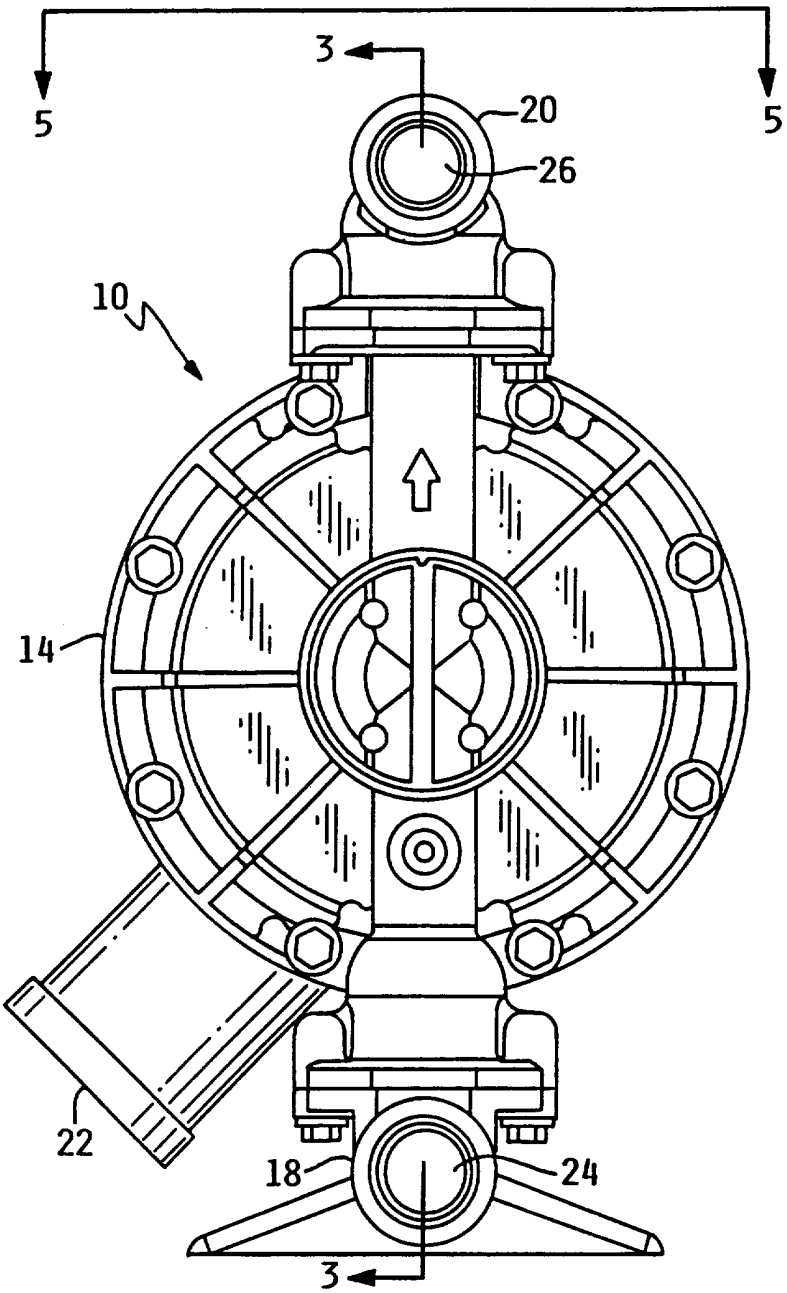

FIG. 1

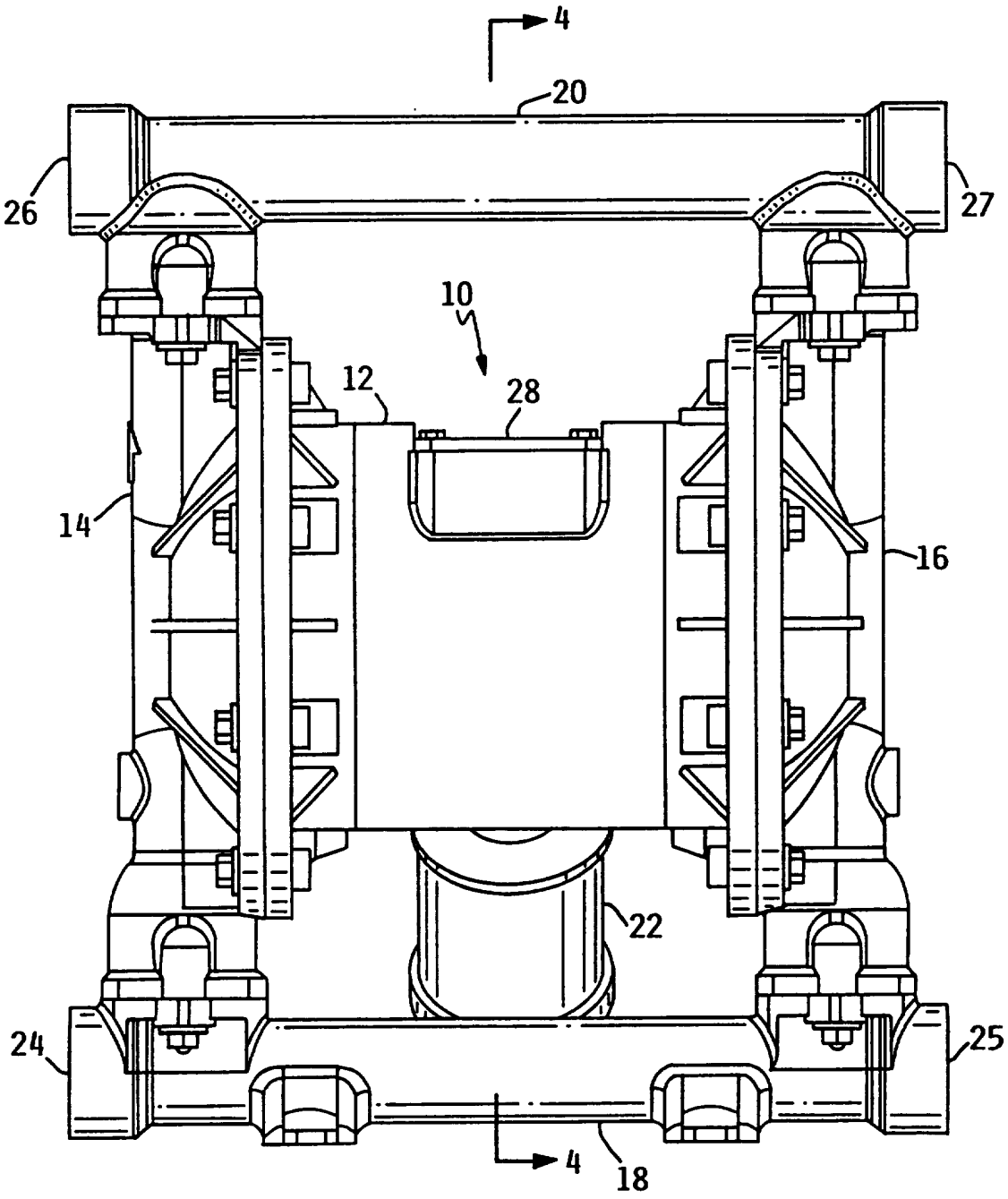

FIG. 2

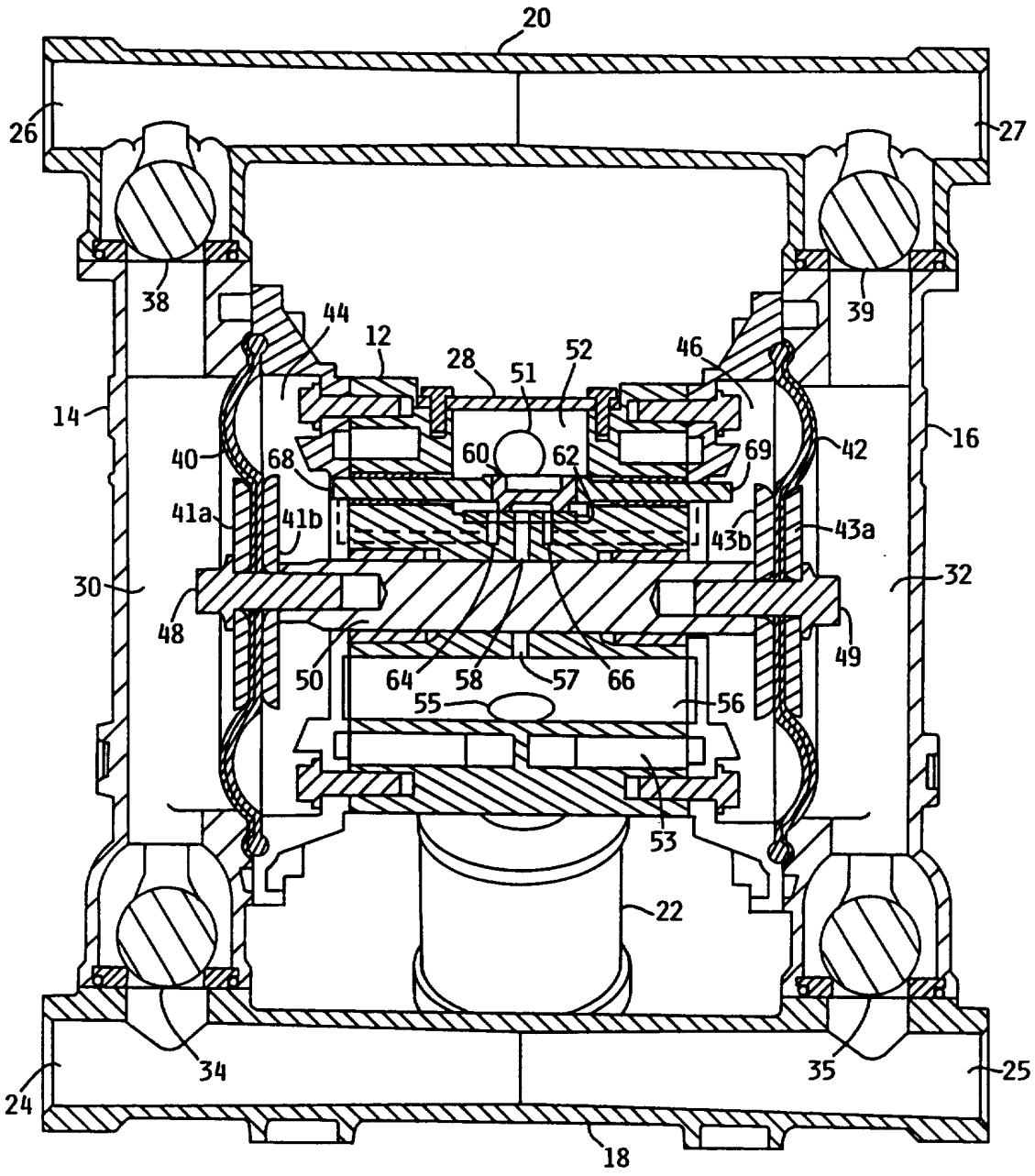
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FIG. 3

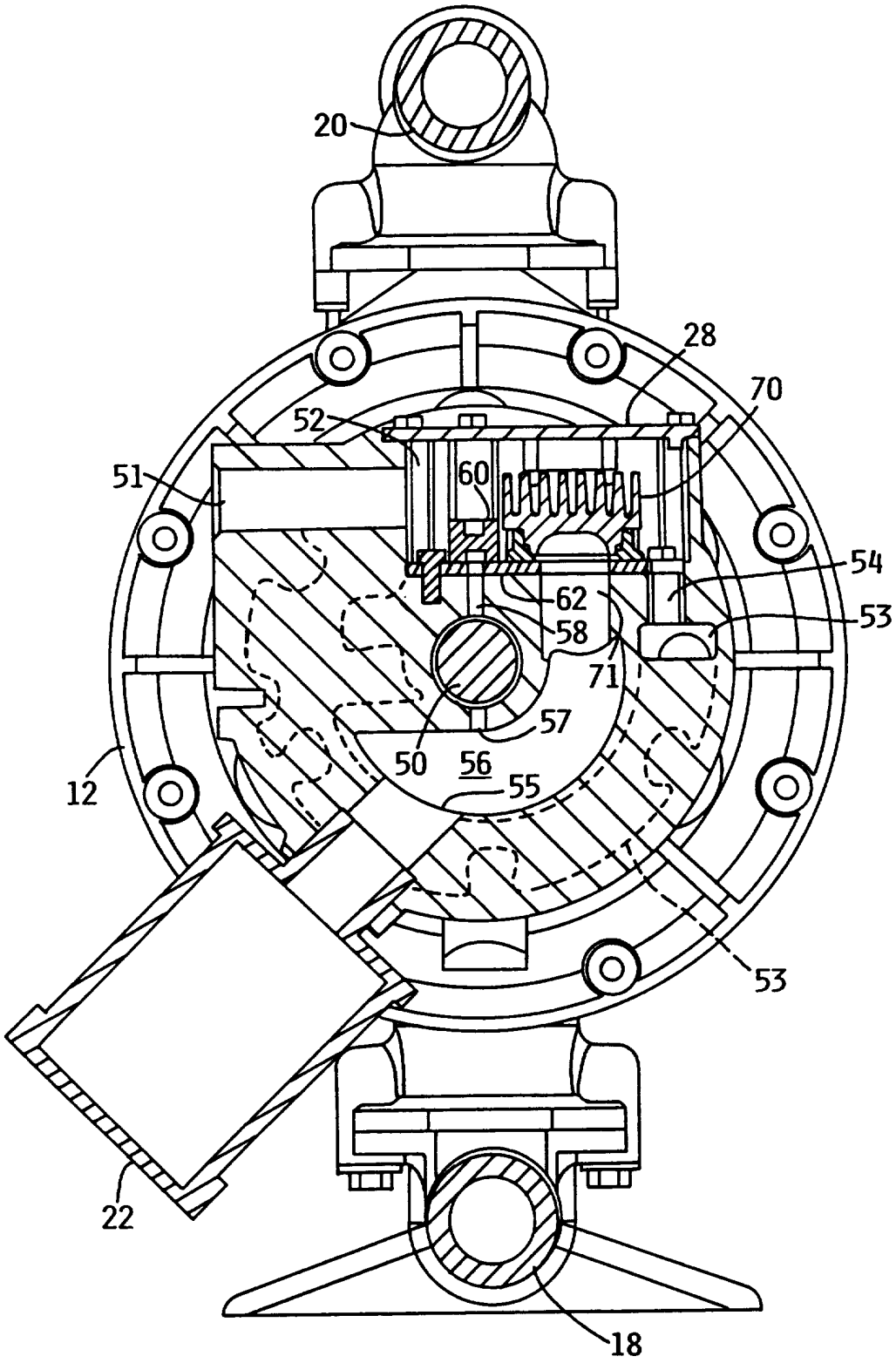

FIG. 4

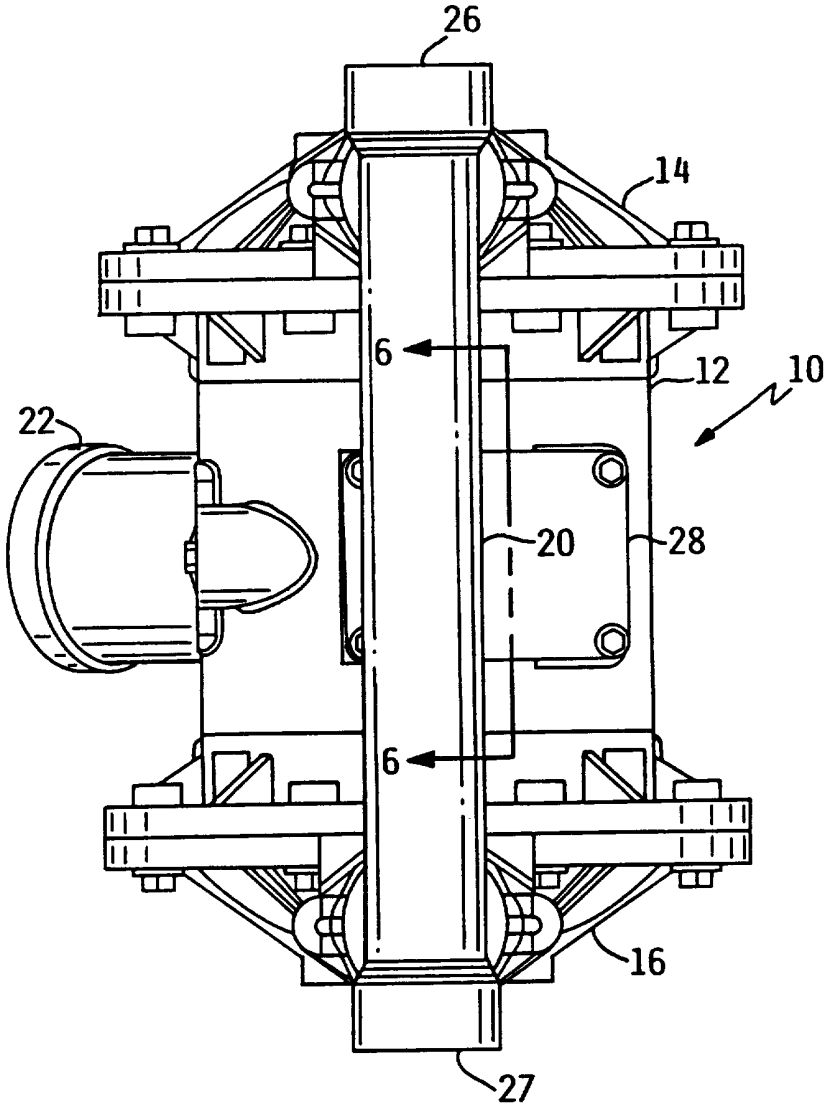

FIG. 5

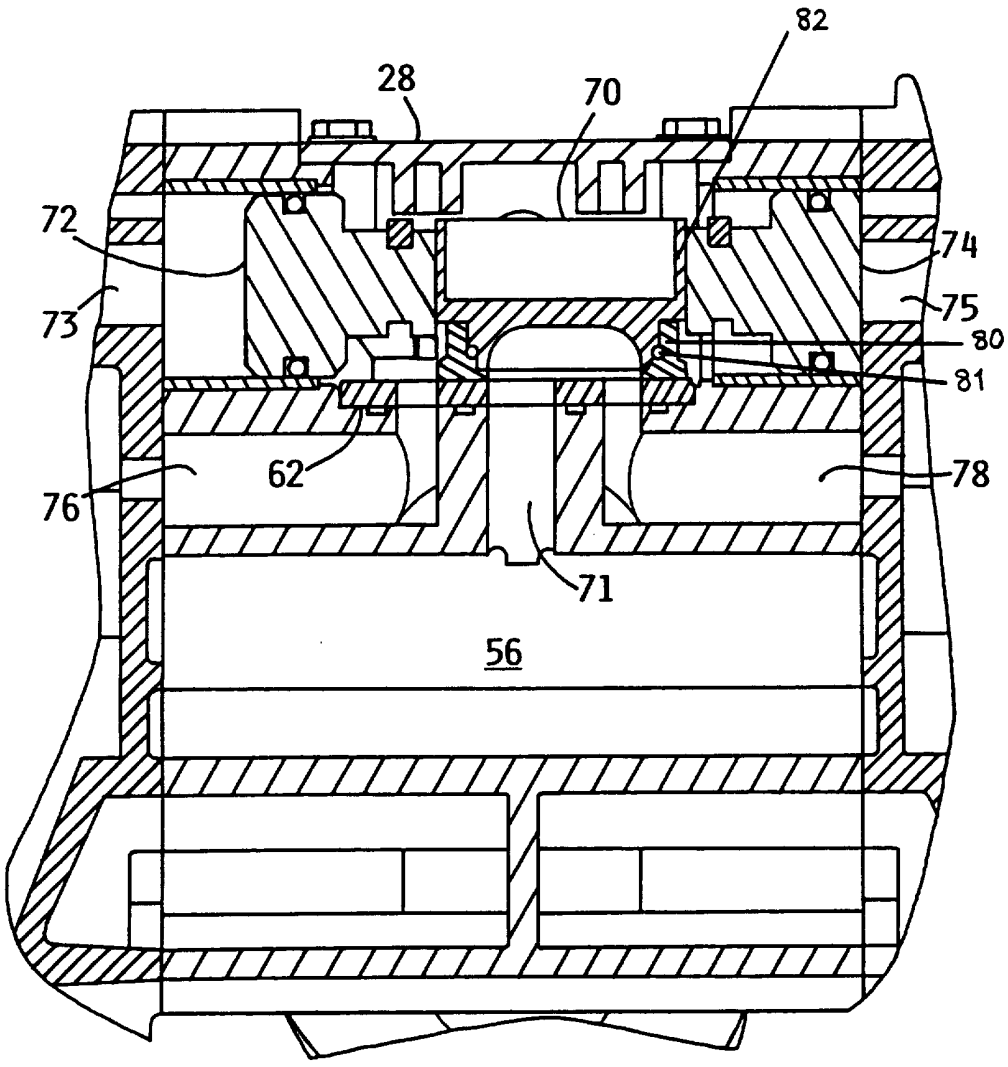

FIG. 6

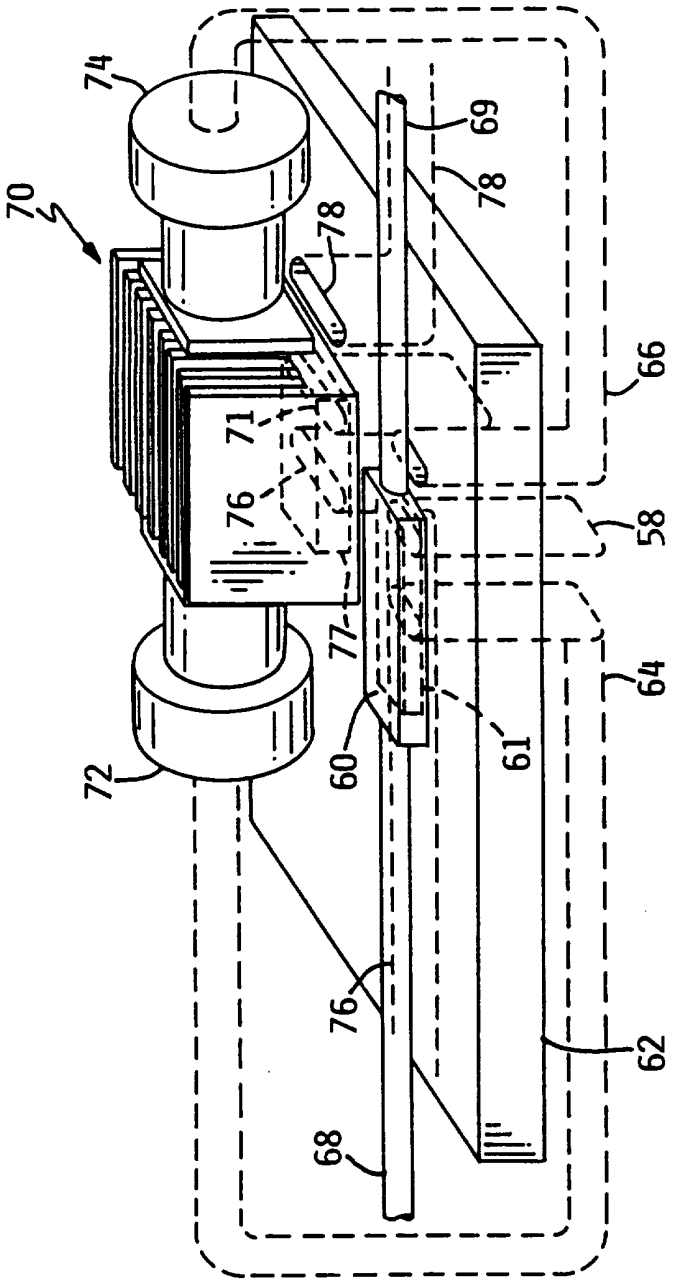

FIG. 7

A TWO-STAGE AIR VALVE ACTUATOR FOR A DOUBLE-DIAPHRAGM PUMP

The present invention relates to a diaphragm pumping apparatus; more particularly, the invention relates to a double diaphragm pump having a two-stage air valve actuator for regulating the pumping action.

Double diaphragm pumps are well known in the art, wherein a source of pressurised air is selectively applied into each of two diaphragm chambers to thereby cause deflection of the respective diaphragms to create a pumping action against liquid materials which are introduced into the diaphragm chamber. Each diaphragm effectively isolates the chamber into two halves, a first half which is susceptible to varying air pressures and a second half which is exposed to the liquid materials being pumped.

The delivery of pressurised air to a double diaphragm pump is typically controlled by an air valve, and the air valve is typically actuated by a mechanical linkage to the diaphragms. Therefore, deflection of one diaphragm causes the actuator to toggle the air valve so as to introduce pressurised air into the diaphragm chamber, which then causes deflection of the second diaphragm until the mechanical actuator toggles the air valve in the reverse direction. This reciprocating movement of the respective diaphragms continues for so long as the pressurised inlet air exceeds the pressure of the liquids confined in the delivery portion of the diaphragm chambers. When the liquid and air pressures equalise, the diaphragms no longer cycle and the pump undergoes what is referred to as a stall condition. This stall condition exists until a pressure imbalance occurs, and the air pressure driving force against the diaphragm again causes diaphragm movement. The valve actuator which controls the flow of pressurised air into the diaphragm chambers is typically mechanically linked to the diaphragms themselves, so as to become actuated at predetermined positions of the diaphragm. In some cases, double diaphragm pumps have utilised a pilot valve mechanically linked to the diaphragm, which then directs the flow of pressurised air to an actuator valve, and the actuator valve

directs the flow of pressurised air to the diaphragm chamber. Various types of spool valves have been utilised for either or both of these valving functions.

The actuator valve which functions to direct the flow of pressurised air into a diaphragm chamber usually simultaneously exhausts the pressurised air from the other diaphragm chamber. The air exhausting through the valve actuator undergoes rapid and sudden decompression causing a dramatic drop in temperature in the proximity of the valve actuator. Repeated exhaust cycles, particularly when the pressurised air has significant moisture content, results in frost build-up proximate the actuator valve and in the exhaust chamber. This frost build-up can accumulate and create an icing effect, which in the extreme can block the further physical movement of the actuator valve and thereby disable the pumping system.

Another problem with prior art double diaphragm pumps relates to the inefficiencies caused by wear of the valve actuators. Valve actuators typically cycle at rates up to several hundred times per minute during the lifetime of the pump, and as these actuators gradually wear, the air seals associated with the actuators undergo leakage which degrades the pressurised operation of the pump. This can eventually lead to pump failure when the leakage condition becomes so excessive as to no longer permit the actuators to operate effectively.

Accordingly, it is an object of the present invention to provide a self sealing actuator valve for a double diaphragm pump which is constructed of a relatively few number of parts and is accessible for maintenance without entirely disassembling the pump.

It is an object of an embodiment of the present invention to provide a pilot valve and actuator valve for a double diaphragm pump wherein both valves constitute sliders over a hardened metal plate.

Other and further objects will become apparent from the following specification and claims and with reference to the appended drawings.

According to one aspect of the present invention there is provided a device for a pump having two diaphragm chambers, each with a liquid pumping section and an air section separated by a diaphragm, the device comprising:

a chamber;

a pilot valve in the chamber for actuation in accordance with predetermined positions of the diaphragms;

an actuator valve in the chamber for actuation in accordance with the actuation of the pilot valve to direct pressurised air into a corresponding air section of one of the diaphragm chambers; and

a removable cover for the chamber.

According to another aspect of the present invention there is provided a double-diaphragm pumping apparatus comprising such a device.

According to a further aspect of the present invention there is provided a double-diaphragm pumping apparatus comprising:

a) a housing having a pair of diaphragm chambers aligned along an axis, and having an intermediate housing section;

b) a pair of removable covers, each cover attached to one of said diaphragm chambers, and a flexible diaphragm clamped between each of said covers and said housing;

c) a shaft slidably fitted in said intermediate housing section along said axis, and means for affixing respective ends of said shaft to each of said diaphragms;

d) an actuator valve chamber in said intermediate housing section, and means for conveying pressurised air into said actuator valve chamber;

e) an actuator valve in said actuator valve chamber, having means for selectively conveying said pressurised air to said diaphragm chambers, and having control means for said means for selectively conveying;

f) a pilot valve in said actuator valve chamber, connected to said actuator valve control means, and having means for responding to predetermined positions of said diaphragms to activate said actuator valve control means; and

g) an exhaust chamber in said intermediate housing section, and passages connecting said exhaust chamber to said pilot valve and said actuator valve.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 shows an end elevation view of the pump of the present invention;

Figure 2 shows a side elevation view of the pump;

Figure 3 shows a cross-sectional view taken along the lines 3-3 of Figure 1;

Figure 4 shows a cross-sectional view taken along the lines 4-4 of Figure 2;

Figure 5 shows a top view of the pump taken along the lines 5-5 of Figure 1;

Figure 6 shows a cross-sectional view taken along the lines 6-6 of Figure 5; and

Figure 7 shows an isometric view of the actuator valve assembly.

Referring first to Figures 1 and 2, several elevation views of the invention are shown. A double diaphragm pump 10 has a pump housing 12 to which are affixed a pair of diaphragm covers 14, 16. A liquid inlet manifold 18 is also affixed to housing 12, as is a liquid delivery manifold 20. An air exhaust muffler 22 is removably attached to housing 12. The liquid to be pumped by pump 10 is coupled to either or both of inlets 24, 25, and the pumped liquid delivered by pump 10 is expelled via outlets 26, 27. An actuator valve assembly, to be more fully described hereinafter, is accessible through a removable cover plate 28.

Figure 3 shows a cross-section view of pump 10 taken along the lines 3-3 of Figure 1. First and second diaphragm chambers 30, 32 are respectively formed in diaphragm covers 14, 16. Inlet manifold 18 is coupled to diaphragm chambers 30, 32 via inlet ball checks 34, 35. Delivery manifold 20 is coupled to diaphragm chambers 30, 32 via outlet ball checks 38, 39. A diaphragm 40 is clamped between cover 14 and

housing 12 thereby isolating diaphragm chamber 30 from diaphragm air chamber 44. A diaphragm 42 is clamped between cover plate 16 and housing 12 to thereby isolate diaphragm chamber 32 from diaphragm air chamber 46. The centre portion of diaphragm 40 is clamped between two plates 41a, 41b, and the plates are affixed to a diaphragm connecting rod 50 by a fastener 48. The centre portion of diaphragm 42 is clamped between two plates 43a, 43b, and the plates are affixed to diaphragm connecting rod 50 by fastener 49. Connecting rod 50 interconnects the two diaphragms 40, 42, and thereby causes the diaphragms to move in coincidence. Connecting rod 50 is slidably movable within a central opening through housing 12, there being sufficient clearance between connecting rod 50 and the central opening to permit the passage of air therebetween.

An actuator chamber 52 is coupled to an air inlet 51, for receiving a source of pressurised air. Air exhaust muffler 22 is coupled to an air outlet 55, which opens into an exhaust chamber 56. An exhaust passage 57 also opens into exhaust chamber 56, and exhaust passage 57 is in flow communication with exhaust passage 58 via the clearance between connecting rod 50 and the opening through housing 12. Pilot valve 60 controls the air flow communication into passage 58 by virtue of its slidable position on valve plate 62. Valve plate 62 has three ports passing therethrough, the centre port being aligned with passage 58. The two outside ports through valve plate 62 are coupled to passages 64, 66. The lower surface of pilot valve 60 is formed into a cup shape, and is referred to as a valve cup. The size of the valve cup is sufficient to permit air flow between any two ports lying beneath the valve cup. In the position shown in Figure 3, pilot valve 60 is positioned to align its underside valve cup in flow communication between passages 66 and 58, thereby providing an exhaust flow connection to exhaust chamber 56. In its alternate position, the valve cup in slide valve 60 provides a flow communication path between passage 64 and passage 58, thereby providing an exhaust flow communication to exhaust chamber 56.

Pilot valve 60 is connected to actuator pins 68, 69, which are respectively horizontally slidable through passages which lead to diaphragm air chambers 44, 46.

Actuator pin 68 connects pilot valve 60 into diaphragm air chamber 44, and actuator pin 69 connects pilot valve 60 into diaphragm air chamber 46. The respective ends of actuator pins 68, 69 may be contacted by plates 41b, 43b, which plates respectively slide the actuator pins horizontally and thereby slide pilot valve horizontally in coincidence. In the view shown in Figure 3, actuator pin 69 projects into diaphragm air chamber 46, and therefore is positioned for contact by plate 43b whenever diaphragm 42 moves leftwardly. The corresponding leftward movement of actuator pin 69 will slide the entire assembly consisting of actuator pin 69, pilot valve 60, and actuator pin 68, thereby causing the end of actuator pin 68 to project into diaphragm air chamber 44.

Figure 4 shows a cross-section view taken along the lines 4-4 of Figure 2. In this view, the exhaust passages are fully visible between air exhaust muffler 22 and pilot valve 60 and actuator valve 70. For example, the exhaust passages associated with pilot valve 60 include passage 58, the clearance around connecting rod 50, passage 57, exhaust chamber 56, and air outlet 55. The exhaust passage 71 from actuator valve 70 is coupled directly into exhaust chamber 56. An outer chamber 53 may be formed in the pump housing 12 in a manner which is shown in dotted outline in Figure 4. Further, an air passage 54 may be formed between outer chamber 53 and inlet air chamber 52, thereby permitting the relatively warmer inlet air to circulate freely throughout outer chamber 53. Outer chamber 53 substantially surrounds the exhaust chamber 56, and the circulation of the relatively warmer inlet air into outer chamber 53 tends to warm the exhaust chamber 56. This warming process reduces the buildup of frost within exhaust chamber 56, and also reduces condensation caused by the passage of the relatively colder exhaust air through the air outlet 55.

Figure 5 shows a top view of pump 10 taken along the lines 5-5 of Figure 1. In this view, the removable cover plate 28 is clearly visible. Figure 6 shows a cross-section view taken along the line 6-6 of Figure 5, illustrating a cross-section view of actuator valve 70. Actuator valve 70 is connected to a pair of slidable piston members 72, 74, which are respectively slidable within cylinder housings. Piston 72 is in flow communication with the pilot valve passage 64 via passage 73; piston 74 is in flow

communication with pilot valve passage 66 via passage 75. The underside of actuator valve 70 comprises a cup-shaped depression which is slidable over valve plate 62. Valve plate 62 has three ports passing therethrough, a centre port in flow communication with exhaust chamber 56 via passage 71, and respective outside ports in flow communication with diaphragm air chambers 44, 46. A first passage 76 connects the first outside port in valve plate 62 to diaphragm air chamber 44; a second passage 78 connects the other outside port in valve plate 62 to diaphragm air chamber 46. In the position shown in Figure 6, actuator valve 70 is positioned to exhaust air from diaphragm air chamber 46 to exhaust chamber 56 by creating an air flow communication path between passage 78 and passage 71. In its alternate position, actuator valve 70 creates an exhaust flow communication path between the passage 76 and the passage 71.

The operation of actuator valve 70 and pilot valve 60 are best illustrated in the isometric view of Figure 7. Pilot valve 60 and actuator valve 70 are formed as slide valves which are slidably movable over valve plate 62. Valve plate 62 has three aligned orifices therethrough for each of the two valves. Pilot valve 60 is slidably moved across the three orifices by actuator pins 68, 69, which in turn are moved by contact with either diaphragm plate 41b or diaphragm plate 43b. In the position shown in Figure 7, pilot valve 60, via its cup-shaped undersurface 62, creates air flow communication between passage 64 and passage 58. Passage 66 is opened into actuator chamber 52, and in operation actuator chamber 52 is filled with pressurised air from air inlet 51. Therefore, the pressurised air in actuator chamber 52 freely passes through passage 66, which is in flow communication with piston 74 associated with actuator valve 70. In its alternate position, pilot valve 60 permits air flow communication between passage 58 and passage 66, thereby uncovering passage 64 to the pressurised air within actuator chamber 52. The pressurised air in actuator chamber 52 can therefore pass freely through passage 64 into contact against piston 72 of actuator valve 70. In either of its operable positions, the pilot valve 60 permits one of the passages 64, 66 to communicate with the exhaust passage 58, while at the same time permitting the other passage to receive pressurised air for communication to one of the pistons 72, 74 associated with actuator valve 70.

Actuator valve 70 is also slidable over valve plate 62, and has a cup-shaped undersurface 77 which permits the pressurised air in actuator chamber 52 to communicate via either passage 76 or passage 78 to one of the diaphragm air chambers. In the position shown in Figure 7, actuator valve 70 is located over the two orifices which provide flow communication between passage 76 and passage 71; passage 71 is the exhaust passage leading to exhaust chamber 56. Therefore, diaphragm air chamber 44 is exhausted via passage 76 to the exhaust air chamber 56, while at the same time diaphragm chamber 46 receives pressurised air via passage 78.

Actuator valve 70 is preferably constructed of several different materials. A valve cup 80 is preferably made from a low-wear, low-coefficient of friction, plastics material; a heat exchanger 82 is preferably made from aluminium or other metallic material having good heat transfer characteristics, and having a plurality of fins for assisting in the heat transfer; the heat exchanger 82 is affixed to the valve cup 80 by an O-ring 81 which compressible fits between the two parts, and provides an air seal therebetween. The pilot valve 60 is preferably constructed from a low-wear, low-coefficient of friction, plastics material. One type of plastics material which performs well in the actuator valve 70 and in the pilot valve 60 is made from acetal with teflon ® fibres.

In operation, the pressurised air is admitted into a first diaphragm air chamber to cause the diaphragm to deflect outwardly, and at the same time to cause the other diaphragm to deflect inwardly. After a predetermined deflection, the inwardly-deflecting diaphragm contacts an actuator pin and causes the pilot valve to slide to a new position over valve plate 62. The pilot valve then permits the flow of pressurised air to a second actuator valve piston, thereby moving the actuator valve to a second position and blocking the flow of pressurised air to the first diaphragm air cylinder while permitting the pressurised air to flow to the second diaphragm chamber. At the same time, the new position of actuator valve 70 permits the first diaphragm air chamber to exhaust to exhaust chamber 56. In this manner, the two diaphragms within pump 10 will continue to cycle for so long as pressurised air is applied to actuator chamber 52, and for so long as the pressure air forces deflecting the respective diaphragms are sufficiently high to overcome the back

pressure of the liquid being pumped. During each inward deflection of a diaphragm liquid is drawn into the diaphragm chamber of the inwardly deflecting diaphragm, while at the same time the other diaphragm is forcing liquid from its diaphragm chamber outwardly through its outlet ball check. This pumping process reverses when the diaphragms deflect in the opposite direction, but in each case the liquid passes inwardly to a diaphragm chamber through one of the ball checks 34, 35, and passes outwardly to the delivery manifold via ball checks 38, 39.

Each time the actuator valve 70 reciprocates, it releases the pressurised air in one of the diaphragm chambers to exhaust chamber 56, and from there outwardly through muffler 22. This causes a rapid decompression of the pressurised diaphragm chamber, and a rapid expansion of the air as it passes into exhaust passage 71 and exhaust chamber 56. This rapid air expansion creates a cooling effect, and lowers the temperature of the exhaust passage walls and actuator assembly as the valve operation continues. If the pressurised air has any significant moisture content, this cooling effect can cause the build-up of frost along the surfaces which are closest to the point of air decompression; i.e. the region adjacent exhaust passage 71. Under certain conditions, this frost build-up can become sufficiently severe so as to block the passages and prevent the actuator valve from any further movement. Therefore, actuator valve 70 is constructed with a metallic heat exchanger to pass heat into the exhaust passage region. The heat exchanger is particularly effective, as it is located within the actuator chamber 52, where there exists a rather continuous flow of pressurised air. The pressurised air which is introduced into actuator chamber 52 is relatively warm air, compared to the exhaust air, and therefore the heat from this air can be transferred via the heat exchanger construction of actuator valve 70 to prevent the build-up of frost.

The present invention may be embodied in other specific forms without departing from the essential attributes thereof; therefore, the illustrated embodiment should be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention.

CLAIMS

1. A device for a pump having two diaphragm chambers, each with a liquid pumping section and an air section separated by a diaphragm, the device comprising:

a chamber;

a pilot valve in the chamber for actuation in accordance with predetermined positions of the diaphragms;

an actuator valve in the chamber for actuation in accordance with the actuation of the pilot valve to direct pressurised air into a corresponding air section of one of the diaphragm chambers; and

a removable cover for the chamber.

2. A device as claimed in claim 1, wherein the actuator valve is slidable.

3. A device as claimed in claim 2, wherein the actuator valve comprises a valve cup in slidable relation with a valve plate, the valve plate having three orifices for respective connection to an exhaust chamber and the two diaphragm chambers.

4. A device as claimed in claim 2 or 3, further comprising two slidable members for actuating the actuator valve in accordance with the actuation of the pilot valve.

5. A device as claimed in claim 4, wherein the actuating members comprise a piston.

6. A device as claimed in any preceding claim, further comprising two pins, each connected at one end to the pilot valve and arranged such that in use, it slides once the predetermined position of a respective one of the two diaphragms has been reached.

7. A device as claimed in any preceding claim, wherein the pilot valve comprises a valve cup in slidable relation with a valve plate, the valve plate having three orifices, one for connection to an exhaust chamber and the other two for connection with the actuator valve.

8. A double-diaphragm pumping apparatus comprising a device as claimed in any preceding claim.

9. A device substantially as hereinbefore described with reference to any one of Figures 1 to 7 of the accompanying drawings.

10. A double-diaphragm pumping apparatus substantially as hereinbefore described with reference to any one of Figures 1 to 7 of the accompanying drawings.

11. A double-diaphragm pumping apparatus comprising:

a) a housing having a pair of diaphragm chambers aligned along an axis, and having an intermediate housing section;

b) a pair of removable covers, each cover attached to one of said diaphragm chambers, and a flexible diaphragm clamped between each of said covers and said housing;

c) a shaft slidably fitted in said intermediate housing section along said axis, and means for affixing respective ends of said shaft to each of said diaphragms;

d) an actuator valve chamber in said intermediate housing section, and means for conveying pressurised air into said actuator valve chamber;

e) an actuator valve in said actuator valve chamber having means for selectively conveying said pressurised air to said diaphragm chambers, and having control means for said means for selectively conveying;

f) a pilot valve in said actuator valve chamber, connected to said

actuator valve control means, and having means for responding to predetermined positions of said diaphragms to activate said actuator valve control means; and

g) an exhaust chamber in said intermediate housing section, and passages connecting said exhaust chamber to said pilot valve and said actuator valve.

12. An apparatus as claimed in claim 11, wherein said actuator valve further comprises a valve cup slidable over a valve plate, said valve plate having three aligned orifices therethrough, the central orifice connected to said passages to said exhaust chamber and each of the other orifices connected to passages leading to one of said diaphragm chambers.

13. An apparatus as claimed in claim 11 or 12, wherein said actuator valve control means further comprises at least one air piston connected to said valve cup, and air passages connected between said at least one air piston and said pilot valve.

14. An apparatus as claimed in any of claims 11 to 13, wherein said pilot valve means for responding to predetermined positions of said diaphragms further comprises a pair of pins slidably mounted in said intermediate housing section and having respective first ends projecting into respective diaphragm chambers, and having second ends connected to said pilot valve.

15. An apparatus as claimed in claim 13 or 14 when dependent upon claim 13 wherein said pilot valve further comprises a valve cup slidable over a valve plate, said valve plate having three aligned orifices therethrough the central orifice connected to said passages to said exhaust chamber, and each of the other orifices connected to passages leading to said actuator valve at least one air piston.

16. An apparatus as claimed in claim 15, when dependent upon claim 14, wherein said pin second ends are connected to said pilot valve cup.

17. An apparatus as claimed in any of claims 11 to 14, further comprising an outer chamber in said housing in close proximity to said exhaust chamber, and a flow passage connected between said outer chamber and said actuator valve chamber.

The Patent Office

Application No:	GB 9603614.0	**Examiner:**	Brian Denton
Claims searched:	1-9	**Date of search:**	3 April 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F1W (WEL)

Int Cl (Ed.6): F04B 43/02 43/06 : F01L 25/06

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0314994 A1 (KOPPERSCHMIDT) whole document	1
A	EP 0147889 A1 (ITT INDUSTRIES) whole document	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.