

July 30, 1963

W. L. CARLSON, JR
FLUID ACTUATOR

3,099,136

Original Filed May 19, 1960

2 Sheets-Sheet 1

FIG. 1

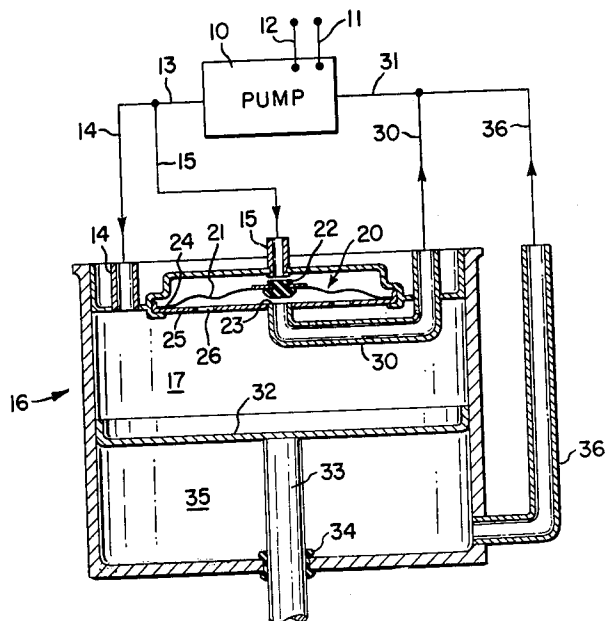
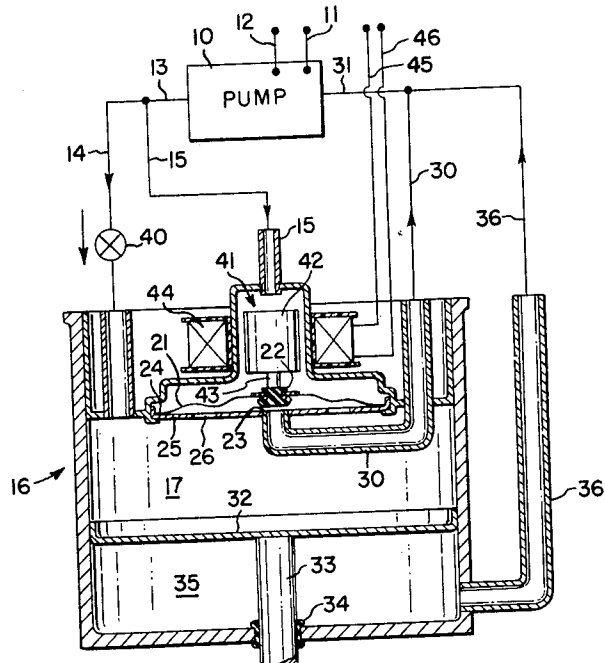


FIG. 2



INVENTOR.
WILLIAM L. CARLSON, JR.

BY *Alfred W. Feldman*

ATTORNEY

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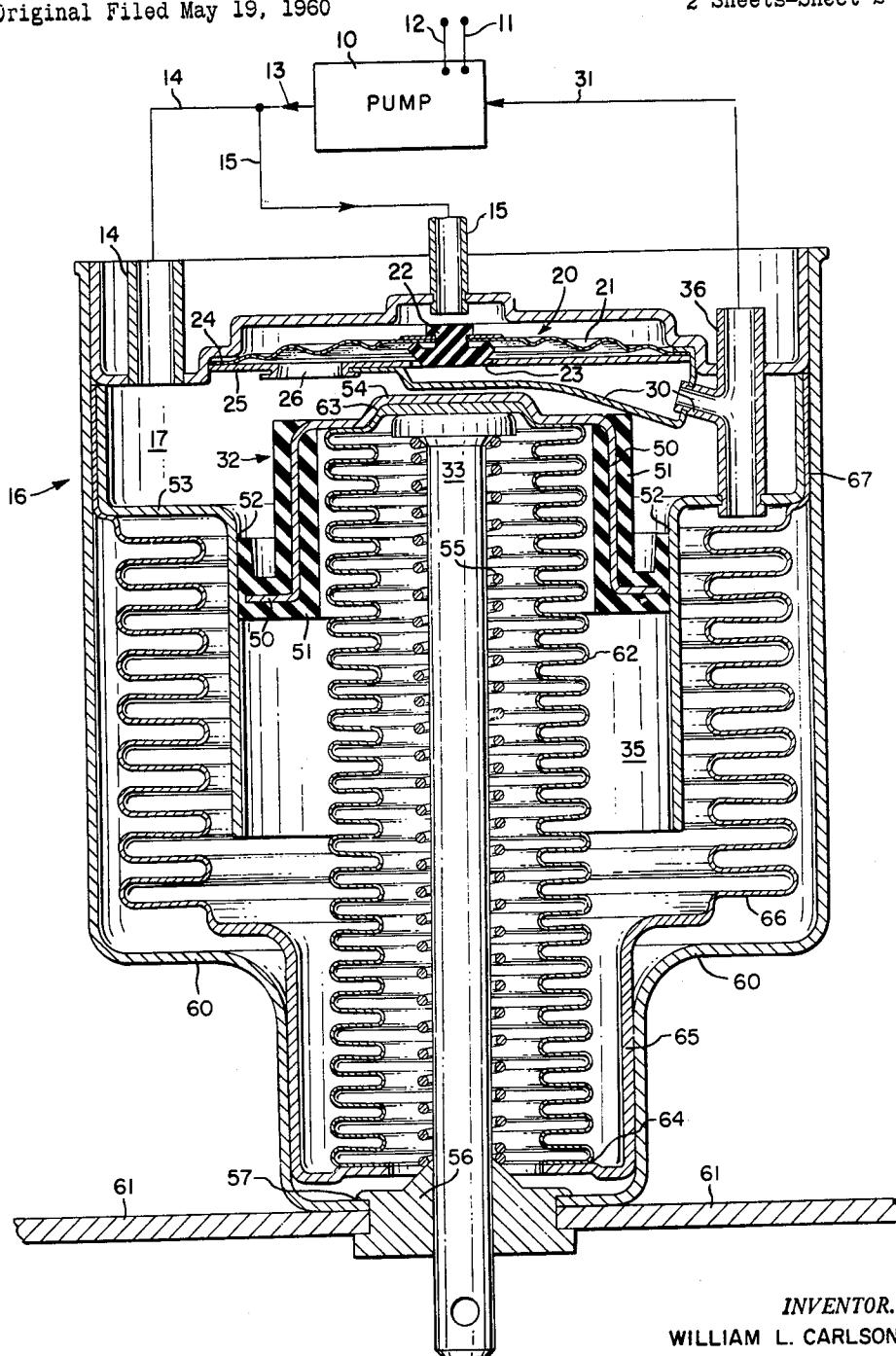


FIG. 3

INVENTOR.
WILLIAM L. CARLSON, JR.
BY *Arfred W. Feldman*
ATTORNEY

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3,099,136

FLUID ACTUATOR

William L. Carlson, Jr., Bloomington, Minn., assignor to Minneapolis-Honeywell Regulator Company, Minneapolis, Minn., a corporation of Delaware
Original application May 19, 1960, Ser. No. 30,211, now Patent No. 3,008,294, dated Nov. 14, 1961. Divided and this application Nov. 2, 1961, Ser. No. 149,677
6 Claims. (Cl. 60—52)

The present invention is broadly directed to a novel type of hydraulic actuator which is particularly adapted for use with conductive fluids such as liquid metals. More specifically, the present actuator utilizes a double bellows sealed shaft and a dump valve that allow the unit to operate rapidly on a return stroke without the impedance of flow of the fluid through the pump that originally supplies the operating pressure to the actuator.

The present application is a division of my co-pending application Serial No. 30,211 filed May 19, 1960, and now Patent Number 3,008,294 issued November 14, 1961.

The use of conductive fluid pumps and actuators is progressively becoming more common and is typified by U.S. Patent No. 2,897,650 and the British Patent No. 810,697. Both of these patents are assigned to the assignee of the present invention and disclose the use of electromagnetic conductive fluid pumps with actuators that supply mechanical outputs whenever the conductive fluid pumps are energized, and which allow the conductive fluid to flow back through the open passage of the conventional electromagnetic conductive fluid pumps on their return stroke. Actuators of this general type are generally somewhat slow in returning due to the impedance to flow of the conductive fluid through the channel of an electromagnetic conductive fluid pump. In order to overcome this impedance, the present invention is directed to a dump valve which operates on a pressure differential in the actuator to allow for the pump to be bypassed on the return stroke, thereby allowing for rapid return of the conductive fluid from a pressure chamber of the actuator to a reservoir chamber of the actuator. Since this type of unit utilizes a conductive fluid that normally must be hermetically sealed, the present invention is directed to a double bellows sealing arrangement for the reservoir chamber that allows for the rapid response of the unit without adding a separate reservoir chamber as might be needed otherwise.

In the present case, it is the primary object to disclose a dump valve arrangement which is pressure operated and does not rely on fluid flow as does the ordinary check valve or dump valve.

Another object of the present invention is to disclose a dump valve that can be made to operate on power failure to the conductive fluid pump and thereby acts as a safety control.

Yet another object of the present invention is to disclose a dump valve that is subject to both pressure control and to selective electric control for use in actuators where a modulation of the actuator is developed by modulating the pressure input to the actuator from the pump.

Still a further object of the present invention is to disclose a dump valve that can be put into a hermetically sealed unit compatible with conductive fluids of the liquid metal type, such as sodium, potassium, or an alloy of sodium-potassium referred to as NaK, and which is exceedingly simple and reliable.

Yet a further object of the present invention is to disclose a dump valve that is exceedingly inexpensive to build into an actuator.

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Another object of the present invention is to disclose a hermetically sealed actuator that can be used with fluids of the corrosive type, as mentioned previously, and that has a double bellows seal so that the reservoir chamber changes in volume readily with operation of the pump and dump valve.

In order to more fully understand the present invention, the invention has been disclosed schematically in FIGURE 1, wherein the dump valve is disclosed;

FIGURE 2 is a similar schematic representation of the invention, but includes an electrical means of operating the dump valve which is shown in the form of a solenoid; and,

FIGURE 3 is a cross section of a production version of an actuator of the type disclosed in FIGURE 1, with the additional feature of the double bellows seal on the output shaft.

Disclosed in FIGURE 1 is a pump 10, preferably an electromagnetic conductive fluid pump having a continuously open fluid flow channel. This type of pump is sometimes referred to as a Faraday type pump and is well known in the art. Electric current is supplied through conductors 11 and 12 from any convenient power source. The pump 10 has an outlet 13 schematically disclosed as supplying a conductive fluid to two conduits or pipes 14 and 15. The pipe 14 passes into an actuator disclosed at 16 to a pressure chamber or area 17. As will be seen in the following description, actuator 16 includes a fluid chamber which is separated into two smaller chambers or areas 17 and 35. The pipe or conduit 15 passes into a valve chamber means 20 that houses the novel dump valve that controls the actuator 16.

The dump valve includes a diaphragm 21 that carries a valve member 22 against a valve seat 23. The valve member 22 is disclosed in its open position which occurs when the pump 10 is deenergized. The diaphragm 21 is sealed at its edge 24 to a plate 25 that forms part of the upper wall of chamber 17 and to valve seat 23. This plate has a number of openings 26 that allow free communication of fluid from the pressure chamber 17 to the underside of the diaphragm 21.

The valve seat 23 is connected to a pipe 30 that returns to the inlet 31 of the pump 10. The upper part of the pressure chamber 17 has its walls sealed to the main walls of the actuator 16 in a fluid tight manner, such as by welding. The pipe 30 is sealed also in a fluid tight manner as it passes through the upper wall of the actuator.

With the arrangement described thus far, the actuator 16 has a pressure chamber 17 that communicates with the underside of the diaphragm 21. The underside of the diaphragm 21 and the fluid chamber are in communication with the pipe 30 through the valve seat 23 which, in turn, allows fluid flow to pass through the pipe 30 to the inlet of pump 10. A second chamber, that is, the valve chamber means 20, is completely sealed from the pressure chamber 17 and is in communication with the outlet of pump 10 through the pipe 15. In order to complete the chamber 17, a piston means 32 is provided to separate the actuator 16 into the previously mentioned two pressure chambers or areas. The piston means 32 has a shaft 33 that is used as output means for the actuator 16. A simple gasket 34 is shown as a sealing means around shaft 33 but it is understood that this is for simplicity in explanation of the operating principles of the unit. A more practical seal is disclosed in FIGURE 3 and will be described in detail in the discussion directed to that figure. The piston means 32 provides a reservoir chamber or areas 35 between the piston means 32 and the side and bottom walls of the actuator 16. A pipe 36 is connected through a lower wall of the actuator 16 to communicate

with the reservoir chamber 35. The pipe 36 connects back to the inlet 31 of the pump 10 and also provides a direct communication between the valve seat 23 and the reservoir chamber 35.

The operation of the device disclosed in FIGURE 1 can best be understood by considering the pressure in chambers 17 and 35 as being equal when the pump 10 is deenergized. At this time, the diaphragm 21 holds the valve 22 off the valve seat 23 to allow a free communication of the fluid that fills the chambers 17 and 35 along with all of the piping and pump 10. Upon application of power to conductors 11 and 12, the pump 10 creates a pressure that forces the fluid filling the system out of the outlet 13 into the conduits 14 and 15. The fluid flowing from outlet 13 through the conduits 14 and 15 supplies a fluid pressure to the pressure chamber 17 and to the valve chamber means 20. The conduits 14 and 15 are arranged so that a pressure drop occurs in the conduit 14, thereby creating a slightly lower pressure in the pressure chamber 17 than occurs in the valve chamber means 20. Since there is little or no flow involved in conduit 15, a larger pressure drop develops in conduit 14 than in conduit 15 due to the frictional flow losses in conduit 14 and this pressure drop moves the diaphragm 21 in a downward direction. The diaphragm carries the valve 22 against the valve seat 23 which immediately seals the pressure chamber 17 and allows a pressure to build up in the pressure chamber to apply a driving force against the piston means 32. It will be understood that the full pump pressure is applied to the diaphragm 21 at this point, whereas a slightly lower pressure is applied to the underside of diaphragm 21 from the pressure chamber 17 via the holes 26. A difference in force across the diaphragm 21 occurs due to a difference in effective areas created by the area of the valve seat 23 being removed from the effective area of the underside of diaphragm 21 due to valve 22 seating on seat 23.

With the pump pressure thus applied and the valve 22 seated against valve seat 23, the full pump pressure operates against the piston means 32 to move the piston means 32 in a downward direction. The movement of piston means 32 downward decreases the volume of the reservoir chamber 35, forcing fluid through conduit 36 into the inlet side 31 of pump 10. When the piston means 32 reaches the bottom of the actuator 16 or operates against a load (not shown) that causes the piston means 32 to stall against the pumping pressure of pump 10, the unit will remain in equilibrium with the pump 10 supplying continuous pressure to hold the piston means 32 in its downward position. Since the pump 10 is of the electromagnetic conductive fluid type, stalling the pump creates no serious problem from a mechanical or electrical standpoint.

As soon as it is desired to return the piston means 32 in an upward direction, it is only necessary to deenergize the pump 10 by removing power from conductors 11 and 12. The load (not shown) connected to shaft 33 is biased in an upward direction by a spring or other suitable means and causes the piston means 32 to want to move upward. Since the pump is deenergized, pressure in chamber means 20 goes to zero while pressure in pressure chamber 17 remains substantially constant since, as stated previously, shaft 33 and its attached piston 32 are biased upwardly by means not shown. This allows the valve 22 to move slightly off the valve seat 23, and opens a direct communication between the pressure chamber 17 and the reservoir chamber 35 through the tube 30. The fluid in pressure chamber 17 is thus immediately dumped through tube 30 into tube 36 and back to the reservoir chamber 35, thereby allowing the piston means 32 to move in an upward direction unimpeded by the fluid passage through the pump 10 from the outlet 13 to the inlet 31.

It can thus be seen that a unique type of dump valve that is pressure operated has been supplied to a hermeti-

cally sealed conductive fluid system and provides for a unique form of operation.

The device disclosed in FIGURE 1 has been modified in FIGURE 2 to add an electric control for the system. This allows for modulation of the unit by pulsing or by varying the pumping pressure created by pump 10. Similar numbers will be utilized for similar parts, and the basic mode of operation of the device in FIGURE 2 is the same as that in FIGURE 1 with the additional features described in detail. The pump 10 again is energized through conductors 11 and 12 to provide a pumping pressure at outlet 13 and through conduit 14 and conduit 15. For convenience in operation, a check valve 40 has been inserted in conduit 14 and prevents fluid from returning to the outlet 13 of the pump during operation of the unit. The actuator 16 is divided by piston means 32 into a pressure chamber 17 and a reservoir chamber 35. The reservoir chamber is connected by pipe 36 back to the inlet 31 of the pump and communicates by pipe 30 with the valve seat 23. The valve seat 23 has a valve 22 cooperating therewith and is carried by the diaphragm 21 which is sealed at 24 as was disclosed in FIGURE 1. Holes 26 again provide communication between the pressure chamber 17 and the underside of the diaphragm 21 so that the fluid pressure in chamber 17 can readily be communicated and permits flow of the conductive fluid in the unit from the pressure chamber 17 to the pipe 30 upon opening of the valve 22.

A valve chamber means 41 is provided which is larger than the valve chamber means 20 of FIGURE 1, to incorporate a solenoid plunger 42 that is supported by a column 43 that is connected to the top of the valve 22 and operates the valve 22 under certain circumstances. Externally mounted to the valve chamber means 41 is a solenoid coil 44 that has a pair of energizing leads 45 and 46 that can be connected to a suitable source of power to energize the coil 44 and thereby create a magnetic field that is utilized to close the valve 22 against the valve seat 23 during energization. The diaphragm 21 is so constructed as to provide a spring effect that holds the valve 22 off the valve seat 23 even with the additional weight of the solenoid plunger 42. If necessary, spring means (not shown) could be added for this purpose. The spring means (not shown) has been left off for clarity in disclosing the present invention.

In operation, the basic principles described in FIGURE 1 apply to FIGURE 2. When the pump 10 is energized by supplying power to conductors 11 and 12, a pressure is applied to the upper side of the diaphragm 21 through the conduit 15 and the valve chamber means 41. Since the valve 22 is off its valve seat 23, the fluid initially flowing from the outlet 13 of the pump when it is first energized flows through the conduit 14 into the pressure chamber 17 from where it flows through ports 26 into the conduit or pipe 30. The pressure thus applied would normally cause the diaphragm 21 to move down and seal the valve seat 23 by applying the valve 22. This action is immediately aided by energizing the conductors 45 and 46 to supply power to the solenoid coil 44. This solenoid coil applies a force to the plunger 42, thereby causing a definite and direct seating of the valve 22 on valve seat 23, regardless of the pressures. With this arrangement it should be understood that the pressure alone on the unit may not be sufficient to operate the diaphragm valve depending on the mode of operation of the unit. It will be noted that if the pump 10 is then deenergized but the solenoid coil 44 is kept energized, the pressure in the pressure chamber 17 cannot be released since the solenoid plunger 42 will hold the valve 22 closed against its seat 23. The check valve 40 prevents reverse flow of the fluid from the chamber 17 to the pump, thereby allowing the unit to be locked in any position regardless of whether or not the pump is energized. By deenergizing the conductors 45 and 46, thereby removing the power to the solenoid coil 44, the valve 22 can be opened by

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the pressure on the underside of the diaphragm 21 increasing due to a movement in an upward direction of the piston means 32.

With the arrangement disclosed in FIGURE 2, it is possible to obtain modulation of the actuator 16 by utilizing either "off-on" operation or by modulating the power to the pump 10. A definite power failure control is also provided since the deenergization of the conductors 45 and 46 will cause the solenoid 44 to allow the solenoid plunger 42 to rise, thereby dumping the valve upon power failure. With the combination of the pumping pressure and the pressure applied by the solenoid plunger 42, it is possible to operate the actuator 16 in various control functions that will be obvious to anyone working in the hydraulic and related arts.

In FIGURE 3, pump 10 is energized through conductors 11 and 12 to supply a fluid pressure at outlet 13 to pipes 14 and 15. Pipe 14 leads directly into the pressure chamber 17 of the actuator generally shown at 16. The pipe 15 leads into the valve chamber means 20 which has a flexible diaphragm 21 that supports the valve member 22. The valve member 22 cooperates with valve seat 23 which is formed in the dividing plate 25. Dividing plate 25 has a hole 26 that allows free communication of fluid from the pressure chamber 17 to the underside of the diaphragm 21. The structure described is substantially identical to the structure schematically represented in FIGURE 1.

The valve seat 23 opens onto a tube 30 which is connected to a return tube 36 to the inlet 31 of the pump 10. In the more refined version of FIGURE 3, the piston means 32 is formed of a piston-like member 50 that is encapsulated in a rubber 51 that forms a tight but sliding seal at 52 to the wall 53 of the actuator 16. Attached by any convenient method to the top 54 of the piston 50 is a stem or shaft 33. Surrounding shaft 33 is a spring 55 that extends to a stop member 56 that is joined at 57 to the outer wall 60 of the actuator 16. The stop 56 acts as a guide for the shaft 33 and also provides a mounting means to a plate 61 that can be a separate mounting plate for the actuator 16 or an integral part of a device to be controlled.

Surrounding the shaft 33 there is a bellows 62 that is attached at 63 between the top of the shaft 33 and the piston top 54 so that the bellows 62 moves in compression whenever the shaft 33 is caused to move in a downward direction. The bellows 62 is sealed at 64 to a cup-like member 65 that forms the lower end of a second concentric bellows 66. The second or concentric bellows is attached to the outer wall 60 of the actuator 16 at 67. The attachment of bellows 66 at 67 is such that the pipe 36 connects into the volume between the bellows 66 and 62 to form the reservoir chamber 35. The area between the bellows 66 and the outer wall 60 of the actuator 16 is utilized to assemble the unit and to form a protective wall for the thin bellows members that actually retain the conductive fluid utilized in the present device.

In considering the operation of the device disclosed in FIGURE 3, its operation is identical to that of FIGURE 1. This operation is that upon energization of pump 10 fluid is caused to flow through pipes 14 and 15. A pressure differential is developed between the pressure chamber 17 and the valve chamber means 20 to cause the valve member 22 to lower against valve seat 23 to cut off a return path for the fluid. The return path would be from the pressure chamber 17 through opening 26 through the valve seat 23, into tube 30, and back to the inlet 31 of pump 10. As soon as valve 22 seats on valve seat 23, the full pump pressure is applied to the top of the diaphragm 21 thereby locking the diaphragm in a down position and applying the full pumping force of pump 10 to the top or outer surface of the piston means 32. Since the piston means 32 is sealed at 52 to the walls 53 of the actuator 16, the piston means

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32 is caused to move in a downward direction. The movement in a downward direction compresses the spring 55 and also begins to collapse the bellows 62 which forms one wall of the reservoir chamber 35. As the bellows 62 collapses, fluid is withdrawn from the reservoir chamber 35 through the pipe 36 to the pump 10. Due to the physical size of the pressure chamber 17 there is required, at this time, more fluid than the smaller chamber 35 could supply if it were merely sealed with a single bellows. As this volume of fluid is pumped through pump 10, the bellows 66 is also caused to collapse causing an upward movement of the cup-shaped member 65 which also reduces the volume of the reservoir chamber 35.

With the present arrangement the collapse of the two bellows, which are in concentric relationship with one another and have a common lower sealed edge, there is provided a reservoir that is capable of supplying all of the fluid needed for the upper or pressure chamber 17 without supplying an external reservoir of any type for the present unit. With both bellows 62 and 66 collapsing the fluid in the lower portion of the reservoir chamber 35 is utilized even though this portion of the chamber is not occupied by the piston means 32 when it has reached its most downward position. The movement of the shaft 33 and the compressing of bellows 62 compresses the spring 55. The compressed spring 55 is the return force utilized to cause the piston means 32 to move in an upward direction upon deenergization of the pump 10.

As was pointed out in connection with FIGURE 1, when pump 10 is deenergized the spring 55 will tend to move the piston means 32 upward slightly. This slight upward movement applies a greater pressure to the underside of diaphragm 21 than exists on the upper side of the diaphragm since the pump 10 no longer is the pressure source. This change in pressure allows the diaphragm to assume its normal position which opens a free fluid passage from the pressure chamber 17 through the opening 26 and the valve seat 23 to the pipe 30. This allows fluid to flow directly back through pipe 30 and pipe 36 into the reservoir chamber 35 thereby completely bypassing the limited passage of the pump channel.

The present invention has been disclosed as operable with a conductive fluid when utilized with an electromagnetic conductive fluid pump. The device is considered to be hermetically sealed at all joints by any convenient means, as welding or soldering. It is understood that the applicant does not wish to be limited to this arrangement solely, but wishes to be limited only by the scope of the appended claims. There are many modifications of the present invention that would be adaptable to various forms of pumps and actuators and the schematic representation along with one preferred embodiment has been presented as an example of one usable embodiment of the present invention.

I claim as my invention:

1. An actuating device comprising: a fluid filled chamber having a plurality of fixed rigid walls and a flexible wall; an actuating member movably mounted within said chamber and dividing said chamber into first and second fluid filled areas on opposite sides of said actuating member; means providing fluid communication between said first and second areas; means external of said chamber for causing movement of said actuating member; said actuating member being in operative engagement with one portion of said flexible wall for movement thereof; said flexible wall being deformable upon movement of said one portion thereof to maintain a constant volume in said chamber; and output means external of said chamber and positioned to be movable by movement of said one portion of said flexible wall.

2. In an actuating device: a fluid filled chamber comprising a fixed wall portion and sealing means including a movable wall having two relatively movable sections; an actuating member movably mounted within said cham-

ber and dividing said chamber into first and second fluid filled areas on opposite sides thereof; means providing fluid communication between said fluid filled areas; said actuating member operably engaging one of said sections of said movable wall for movement thereof; means external of said chamber and operable to cause movement of said actuating member; the other of said sections of said movable wall being effective upon movement of said one of said sections to move oppositely thereto to maintain a constant volume in said chamber; and output means external of said chamber and adapted to be positioned by the movement of said one of said sections of said movable wall.

3. An actuating device comprising: a fluid filled chamber having a plurality of fixed rigid walls and a flexible wall; an actuating member movably mounted entirely within said chamber and dividing said chamber into first and second fluid filled areas on opposite sides of said actuating member; means adapted to establish fluid communication between said first and second areas; means external of said chamber for causing movement of said actuating member, said actuating member being in operative engagement with one portion of said flexible wall for movement thereof; said flexible wall being movable upon movement of said one portion thereof to maintain a constant volume in said chamber; and output means external of said chamber and adapted to be positioned by movement of said one portion of said flexible wall.

4. An actuating device comprising: a chamber having a fixed portion and a movable wall, said movable wall having two relatively movable sections; a pressure movable member positioned within said chamber and dividing said chamber into a pressure area and a reservoir area on opposite sides thereof, said reservoir area including said movable wall, said pressure movable member engaging one of said relatively movable sections of said movable wall for movement thereof; said chamber being substantially filled with a fluid; means adapted to connect said pressure area and said reservoir area through external fluid control means; and an output member operably engaging said one of said relatively movable sections of said movable wall for movement therewith; said movable wall being arranged so that the other of said relatively movable sections is movable to maintain a constant volume in said chamber regardless of the position of said one of said relatively movable sections.

5. An actuating device comprising: a chamber having a fixed portion including a plurality of fixed walls and a movable portion including a pair of concentric bellows rigidly and sealingly connected together at one of their ends, the other end of the outer one of said bellows being fixed to said fixed portion; a pressure movable member positioned within said chamber and dividing said chamber into a pressure area and a reservoir area on opposite sides thereof, said reservoir area including said movable portion, said pressure movable member engaging the other end of the inner one of said pair of bellows for movement thereof; said chamber being substantially filled with a fluid; means adapted to connect said pressure area and said reservoir area through a fluid pump; and an output member operably engaging said other end of the inner one of said bellows for movement therewith; said bellows being arranged so that the connected ends thereof are movable to maintain a constant volume in said chamber regardless of the position of said other end of said inner one of the concentric bellows.

6. An actuator comprising: a fluid filled chamber having a fixed portion and a movable wall; said movable wall including a pair of concentric bellows rigidly connected together at one of their ends; the other end of the outer one of said bellows being fixed to said fixed portion; said chamber including a pressure area and a reservoir area separated by a member movable in response to pressure in said pressure area; the other end of the inner one of said pair of bellows being in operative engagement with said pressure movable member for movement therewith and adapted for operative engagement with an output member to transmit motion thereto; and means adapted to establish communication between said pressure area and said reservoir area through external fluid control means; said bellows being arranged so that when said other end of said inner bellows is moved in one direction relative to said chamber, the ends of said bellows which are connected together are moved in an opposite direction thereto to maintain a constant volume in said chamber.

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