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DIAPHRAGM PUMPING SYSTEM

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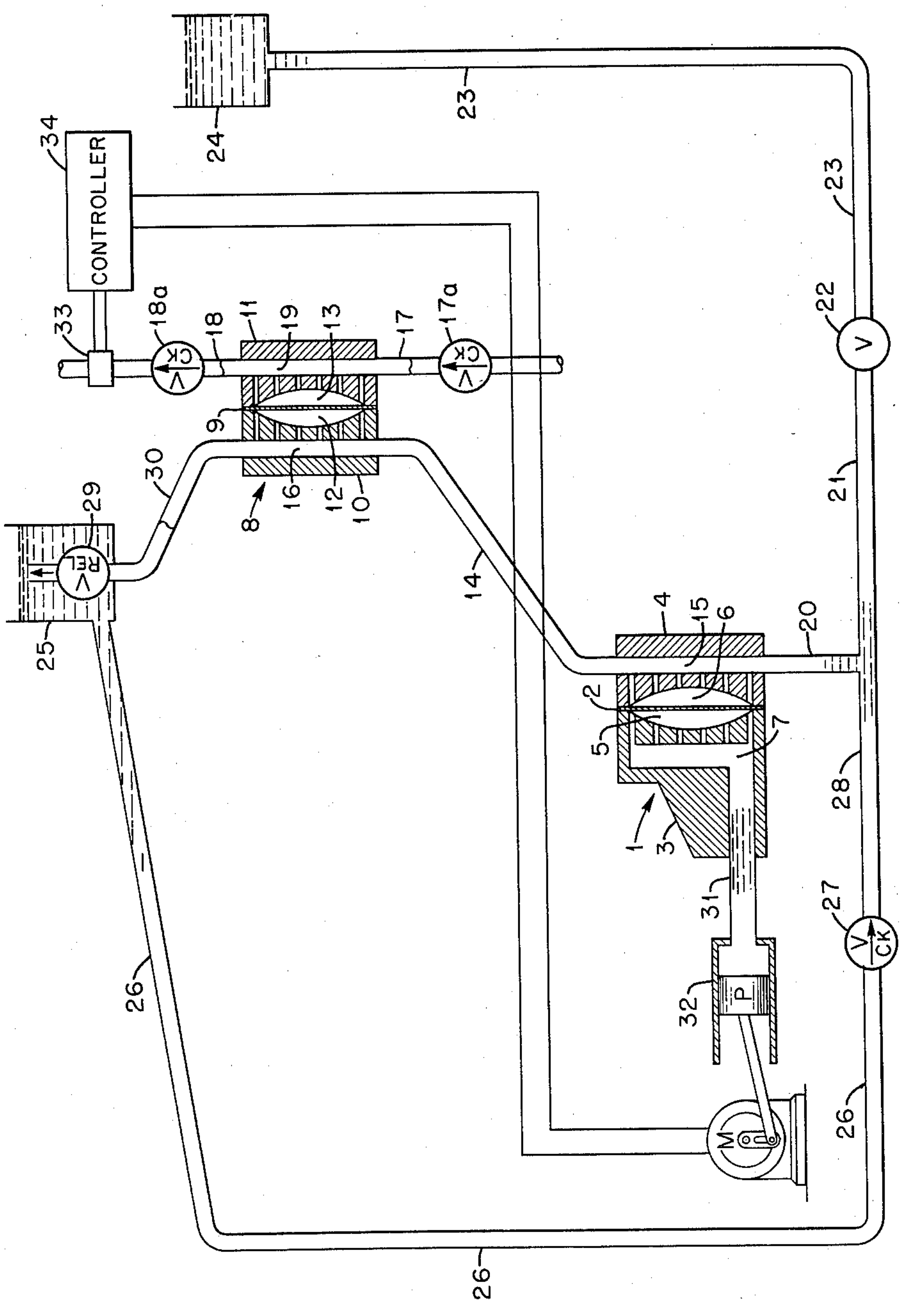

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DIAPHRAGM PUMPING SYSTEM

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The present invention relates generally to pumps. More particularly, it relates to a novel hydraulically-actuated diaphragm pumping system capable of automatically rephasing itself during normal operation.

Hydraulically actuated diaphragm pumps consist of a pump head defining an internal cavity, a pumping diaphragm mounted within the cavity and adapted to oscillate therein, an externally-located, reciprocating driving source, and an intermediate fluid coupling system adapted to hydraulically couple the driving source to the pumping diaphragm with an incompressible fluid. The reciprocating action of the driving source is hydraulically transmitted through the fluid coupling system to oscillate the pumping diaphragm and thereby circulate a fluid.

Usually the driving source of such pumping systems takes the form of a reciprocating piston pump. When these systems are used to circulate highly corrosive, reactive, or radioactive fluids, it is desirable to separate the fluid in contact with the piston pump from the pumping diaphragm to eliminate contamination in case of a leak in the pumping diaphragm. This is usually accomplished by using a double diaphragm system. Such systems comprise a pumping diaphragm, as above, and a driving diaphraghm, the two diaphragms being hydraulically coupled by an incompressible fluid. The reciprocating driving source, a reciprocating piston pump, for example, is coupled to the driving diaphragm. The reciprocating action of the driving source is transmitted to the pumping diaphragm through the driving diaphragm. It should be apparent that such double diaphragm systems are in all essential respects identical to the single diaphragm system described above, if the driving source is considered to be a reciprocating pump hydraulically coupled to a driving diaphragm.

Hydraulically-actuated diaphragm pumps, whether of the single or double diaphragm type, are highly advantageous because the pumping diaphragm can be remotely located with respect to the driving source. This aspect makes the pump highly useful in circulating radioactive fluids in the nuclear energy field because only the pumping diaphragm need be located behind protective shielding.

Diaphragm pumps operate properly only as long as the pumping diaphragm and the driving source oscillate in phase with each other. If the volume of the fluid, which couples the driving source to the pumping diaphragm, changes or compressible gas enters or is released within the coupling system, the two components fall out of phase.

The consequences of a pumping diaphragm's being out of phase with its driving source can be quite serious. First, at any given rate of oscillation, the capacity of a system which is out of phase is less than a system which is in phase. Thus, in order to maintain the pumping rate of an out-of-phase system at the in-phase rate, either the rate of oscillation or, if possible, the displacement of the pump must be increased. Obviously, there are upper limits on both the oscillation rate and the displacement for a given system, and once these limits are reached, the capacity of the system cannot be maintained at the desired level. Secondly, if a sufficient volume of compressible gas accumulates in the coupling system, the pumping action can cease altogether because the driving source

merely compresses the included gas without oscillating the pumping diaphragm.

In the past, diaphragm pumping systems have been put back into phase by manually readjusting the diaphragm position, the driving source position, and the coupling-fluid volume. Obviously, the inconvenience of such a procedure detracts greatly from the utility of diaphragm pumping systems. The procedure is even more inconvenient when the pumping system is in a radioactive environment.

Thus, it is a general object of the present invention to provide a diaphragm pumping system which automatically rephases itself during normal operation.

A further object of the invention is to provide a pumping system which automatically eliminates from its coupling system any gases which may accumulate therein.

A still further object of the invention is the provision of a diaphragm pumping system which automatically adjusts itself to changes in coupling-fluid volume caused by temperature changes.

Other objects of the invention will become apparent from an examination of the following description of the invention and the drawing appended thereto, wherein:

The FIGURE is a schematic representation of a diaphragm pumping system adapted to meet the above-listed objects.

In accordance with the principles of the present invention, the above-stated objects are attained by providing a diaphragm pumping system having a driving source of variable displacement, the normal displacement being equal to and the maximum displacement being greater than the displacement of the pumping diaphragm. A pressure relief valve is provided in the coupling system, and a flow detection device and a controller responsive thereto are provided to temporarily increase the displacement of the driving source if the flow output of the pumping diaphragm falls below the desired pumping rate. In addition, a fluid reservoir linked to the intermediate fluid system through a one-way valve such as a check valve is provided.

To facilitate the understanding of the invention, reference is made to the single figure which is a schematic representation of a double diaphragm pumping system incorporating the essential features of the invention. Primary unit **1** consists of a driving diaphragm **2** mounted between two confronting pumping heads **3** and **4**, which are provided with dish-shaped cavities **5** and **6**, respectively. Pumping head **3** is provided with inlet plenum **7**, the function of which will be described below.

Remote unit **8** similarly consists of a driven or pumping diaphragm **9** mounted between two confronting pumping heads **10** and **11**, which are provided with dish-shaped cavities **12** and **13**, respectively. Cavity **12** of remote unit **8** and cavity **6** of primary unit **1** are linked hydraulically by an intermediate conduit **14**, which communicates therewith through an outlet plenum **15** and an inlet plenum **16** provided in pumping heads **4** and **10**, respectively. Cavity **13** of pumping head **11** of remote unit **8** communicates with an inlet conduit **17** containing a check valve **17***a* and an outlet conduit **18** containing a check valve **18***a* through plenum **19**. Outlet line **18** is provided with a flow sensing device **33**, comprising an orifice and differential pressure taps, which is connected to a differential-pressure-responsive pump controller **34**.

Intermediate conduit **14** and plenums **15** and **16** form the intermediate coupling system which is filled with an incompressible fluid during operation of the pumping system. Communicating with plenum **15** of the intermediate system through conduits **20** and **21**, valve **22**, and conduit **23** is a fluid supply reservoir **24**. An overflow reservoir **25** communicates with plenum **15** through conduit 26, check valve 27, conduit 28 and conduit 20, and with plenum 16 through pressure relief valve 29 and conduit 30.

Cavity 5 of primary unit 1 communicates through plenum 7 and a conduit 31 with a self-adjusting variable-displacement, reciprocating-piston pump 32. Such pumps are commercially available. A fluid occupies the space between the piston of pump 32 and diaphragm 2; therefore, the reciprocating action of the piston causes oscillation of diaphragm 2 between heads 3 and 4 of the primary unit.

In operation, the intermediate system (i.e., cavities 6 and 12, plenums 15 and 16, and conduit 14) and all communicating conduits on the intermediate-system side of the valves (i.e., conduits 20, 21, 28 and 30) are filled with an incompressible fluid. Valve 22 is closed and since check valve 27 alloys fluid flow only in the direction indicated by the arrow, the two diaphragms are linked by a closed hydraulic system. Therefore, oscillation of driving diaphragm 2 induced by reciprocating pump 32 will be reflected by similar oscillation of pumping diaphragm 9 in remote unit 8. If diaphragm 2 is moved toward pumping head 3, diaphragm 9 will be drawn toward pumping head 10. The pressure in cavity 13 of remote unit 8 will decrease allowing the liquid being pumped to flow into the cavity through check valve 17*a* and inlet conduit 17. A subsequent movement of diaphragm 2 of primary unit 1 toward pumping head 4 will cause diaphragm 9 of remote unit 8 to move toward pumping head 11, thereby forcing the fluid being pumped out through outlet conduit 18 and check valve 18*a*. Thus, regular oscillation of diaphragm 2, induced by the reciprocating action of pump 32, causes oscillation of diaphragm 9 of remote unit 8 which provides a pulse-type unidirectional pumping action to a fluid contained in pumping head 11.

As was stated above, any change in volume of the intermediate coupling fluid will cause the diaphragms to fall out of phase with each other. For example, if the volume of coupling fluid decreases, driving diaphragm 2 cannot force pumping diaphragm 9 to its fully extended position against the concave surface of pumping head 11. Therefore, the output of remote unit 8 will decrease. Similarly, if a compressible gas enters the coupling system, a portion of the action of diaphragm 2 will be absorbed in compressing the gas and diaphragm 9 will not be forced into its fully extended position against pumping head 11. Such conditions are automatically corrected, however, in the following manner. As was previously noted, reciprocating pump 32 is of the self-adjusting variable displacement type; that is, the stroke of the reciprocating piston is variable. In addition the displacement of primary unit 1 exceeds the displacement of remote unit 8. During normal in-phase operation, the displacement of pump 32 is set to be equal to the displacement of remote unit 8. Therefore, diaphragm 2 of primary unit 1 oscillates between the concave surface of, or a point removed somewhat from, pumping head 3 and a point removed from the concave surface of pumping head 4.

If a compressible gas enters the intermediate fluid system or the volume of the fluid contained therein changes, the oscillation of remote diaphragm 9 will be out of phase with diaphragm 2 and the pumping rate through conduit 18 will decrease. Such a change is detected as a decrease in differential pressure by flow sensor 33. In response to the decrease in the differential pressure across flow sensor 33 which reflects the change in flow rate, pump controller 34 actuates the self-adjusting mechanism of reciprocating pump 32, thereby increasing its displacement. The increased displacement causes diaphragm 2 to deflect more than normally on its forward stroke and increase the pressure in the intermediate system, thereby fully deflecting remote diaphragm 9 and opening pressure relief valve 29. Excess fluid and/or gases are thus eliminated from the intermediate system and the fuel pumping capacity of remote unit 8 is restored. On the rearward stroke of diaphragm 2 (i.e., toward the concave surface of pump head 3), the two diaphragms are rephased as follows. Since diaphragm 2 was, on its forward stroke, extended beyond its normal forward terminal position, the liquid volume in the intermediate system was reduced. Therefore, diaphragm 9 arrives at its rearward terminal position against the concave surface of pumping head 10 before diaphragm 2 reaches its rearward terminal position. Diaphragm 2 does, however, continue its rearward deflection toward pump head 3 after diaphragm 9 has come to rest against pump head 10, thereby causing a decrease in the pressure in the intermediate system. This causes check valve 27 to open and admit fluid into the intermediate system. Thus, when diaphragm 2 reaches its rearward terminal position, the two diaphragms are once again in phase and the intermediate system is filled with the proper amount of fluid.

The above purging cycle is repeated until remote unit 8 is operating at the desired capacity, whereupon controller 34 returns reciprocating pump 32 to its original displacement equal to the displacement of pumping diaphragm 9.

Remote diaphragm pumping systems are equipped with two diaphragms only when it is necessary to isolate the fluid in contact with the reciprocating pump (i.e., pump 32) from the fluid flowing on the pumping side of the remote diaphragm (i.e., the fluid flowing through conduits 17 and 18). If such isolation is not required, the primary diaphragm may be eliminated. Thus, in the system illustrated, primary unit 1 could be removed and reciprocating pump 32 allowed to work directly on diaphragm 9. It should be apparent that such a modification would not affect the operation of the present invention, because the piston of pump 32 would be rephased in the same manner as described above in connection with the illustrated, double-diaphragm system.

In addition, it is not necessary that reservoir 25 and return line 26 be present, if fluid can be drawn from reservoir 24. In other words, circulation of the intermediate fluid is not necessary for the invention. Of course, in this event, valve 22 would have to be replaced with a check valve or its equivalent allowing flow only in the direction toward the intermediate system.

Since these and many other modifications of the illustrated embodiment can be made without departing from the spirit and scope of the invention, it is intended that the invention be limited only by the following claims.

Having thus described our invention, we claim:

1. In a diaphragm pumping system, the combination of a first pump head defining an internal cavity; a pumping diaphragm adapted to oscillate within said cavity; a second pump head defining a cavity having a volume greater than the volume of the cavity in said first pump head; a driving diaphragm adapted to oscillate with the cavity of said second pump head; an intermediate coupling system provided with a pressure relief valve and adapted to hydraulically couple one side of the diaphragm of said second pump head to one side of the diaphragm of said first pump head; a reciprocating pump hydraulically coupled to the other side of the diaphragm of said second pum head, said reciprocating pump having a variable displacement, the normal displacement of said pump being equal to and the maximum displacement being greater than the volume of said cavity of said first pump head; flow detection means adapted to monitor the rate of flow output from said diaphragm; means responsive to said flow detection means to temporarily increase the displacement of said reciprocating pump from its normal displacement to a greater displacement whenever the flow output from said pumping diaphragm falls below its full capacity; a fluid reservoir; a conduit communicating with said reservoir and said intermediate coupling system; and a one-way valve located in said conduit allowing fluid flow only in the direction toward said intermediate coupling system.

2. The pumping system of claim 1 wherein said reciprocating pump is a reciprocating piston pump having a variable stroke which is responsive to the flow detection means.

3. The pumping system of claim 1 wherein said pressure relief valve is loacted within said fluid reservoir.

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