

[54] SELF-COMPENSATING DIAPHRAGM PUMP

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388; 60/54.5 R

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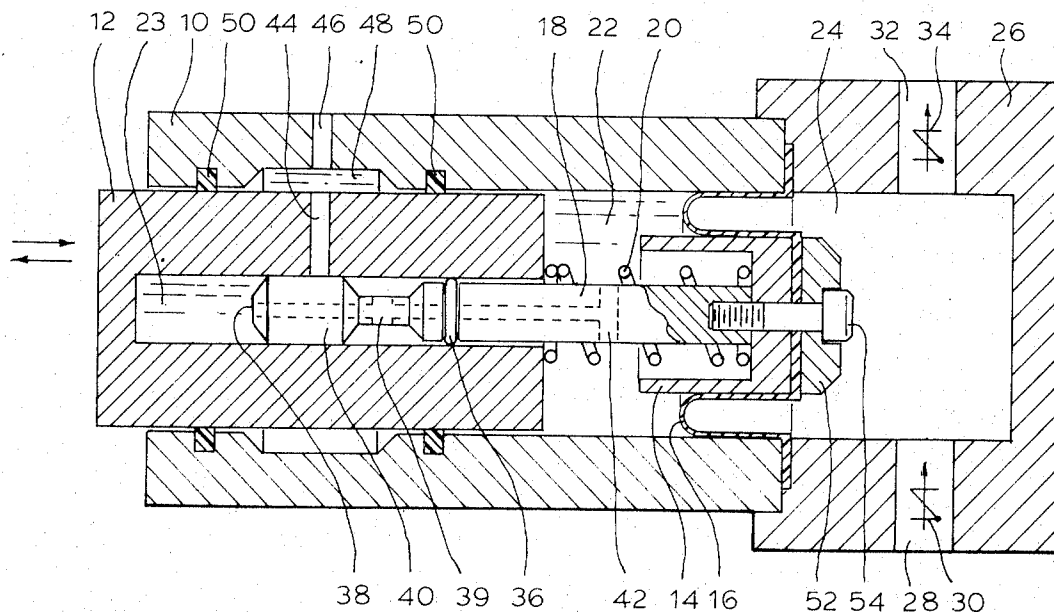
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[57]

ABSTRACT

A self-compensating diaphragm pump wherein a valve arrangement operating according to the diaphragm position permits hydraulic fluid from a reservoir maintained at a pressure greater than the pump inlet pressure and less than the pump outlet pressure to compensate for hydraulic fluid volume variations in the piston chamber adjacent the diaphragm.

19 Claims, 5 Drawing Figures



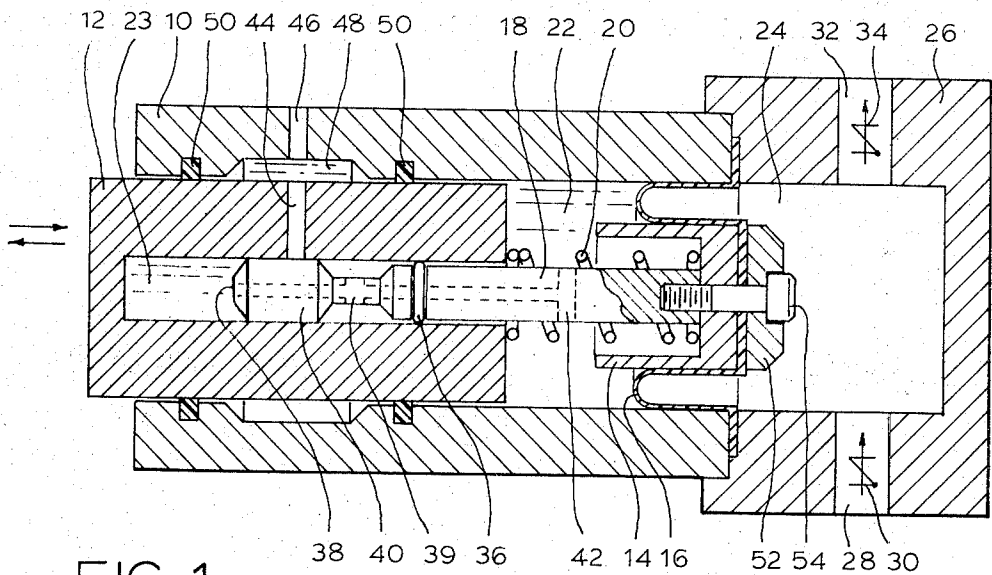


FIG. 1

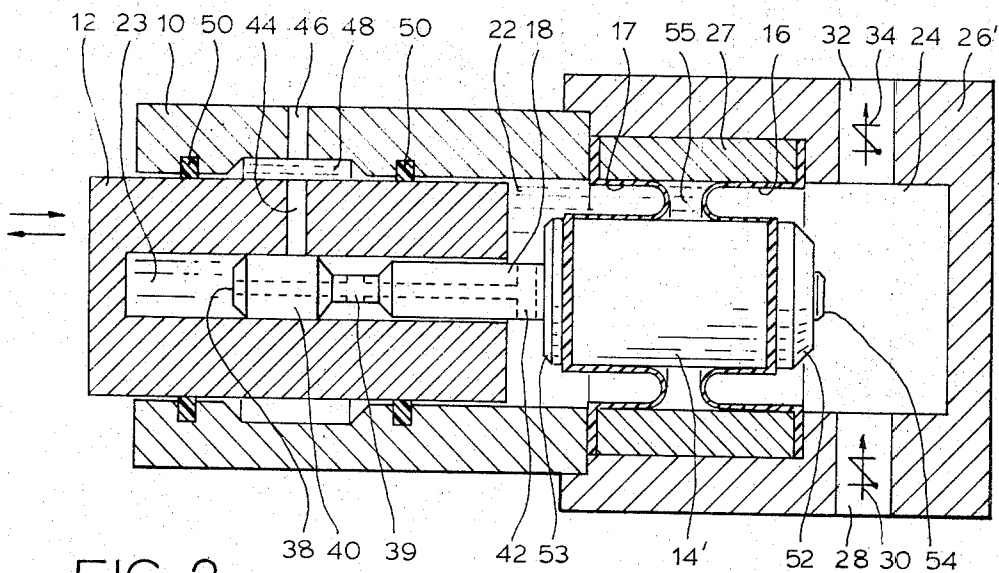
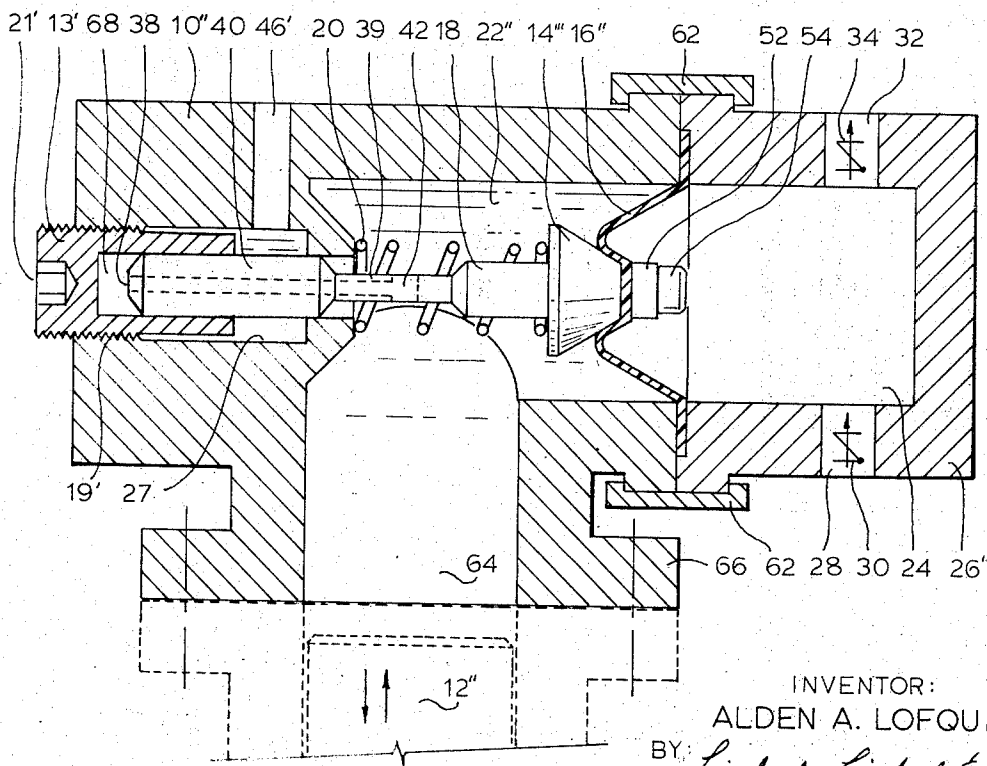
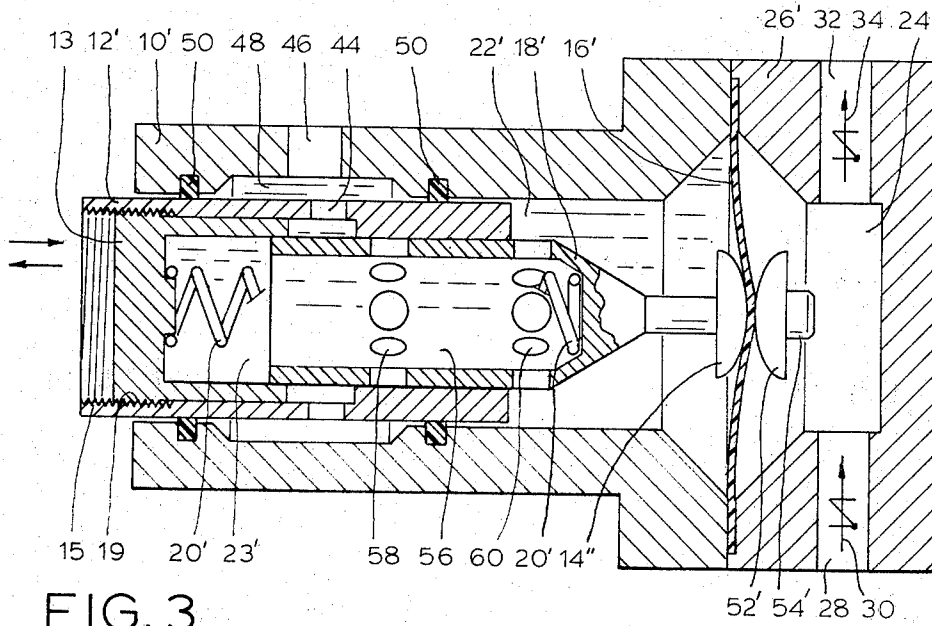


FIG. 2

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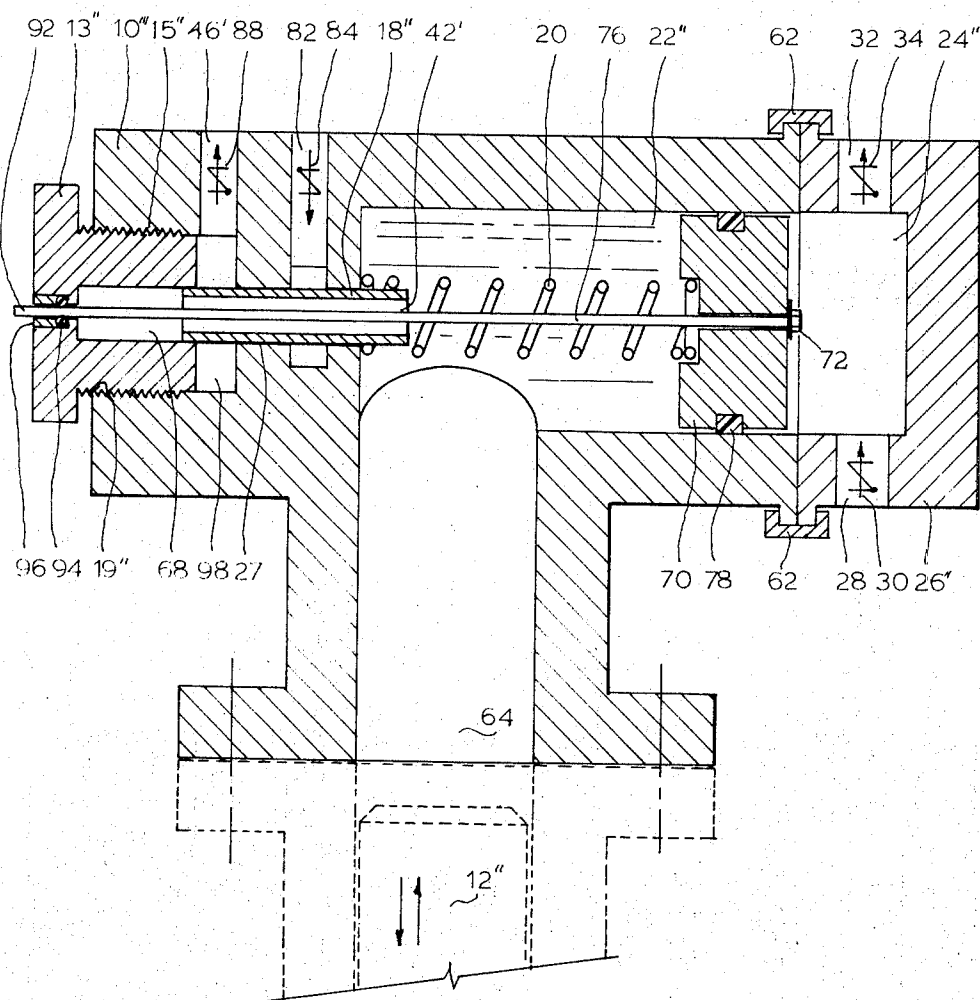


FIG. 5

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SELF-COMPENSATING DIAPHRAGM PUMP

BACKGROUND OF THE INVENTION

This invention relates to improvements in the design and construction of reciprocal pumps and more particularly to a diaphragm pump that is self-compensating for variations in piston chamber hydraulic fluid volume. One type of prior art rolling seal pump is disclosed in U.S. Pat. No. 3,488,763, issued Jan. 6, 1970 to the present inventor.

One problem encountered in a rolling seal diaphragm pump with fluid backing chamber is the requirement for maintaining a relatively constant hydraulic fluid volume supporting the diaphragm so that substantially constant pressures are provided on both sides of the diaphragm. In order to maintain such a constant hydraulic fluid volume the prior art has typically provided elaborate sealing members to minimize fluid loss and/or has provided auxiliary pumping systems to replace lost fluid. One example of the latter approach is U.S. Pat. No. 3,277,795, issued Oct. 11, 1966 to J. A. Rietdijk.

In accordance with the present invention the loss of hydraulic fluid through leakage or diffusion, etc. is automatically compensated without the resort to an elaborate auxiliary system. The principles of the invention are equally applicable to all types of diaphragms of various materials and configurations. It will also be apparent to those of ordinary skill in the art that the invention is also applicable to hydraulic devices using bellows. Thus, the term "diaphragm" as used herein and in the claims is intended to cover not only diaphragms of various shapes, materials, and rigidity, but also bellows and other means of separating one volume or space from another such volume or space.

Means are provided to control a two-way valve in accordance with the volume of hydraulic fluid in the pump. The valve permits fluid to flow in or out to or from a reservoir as necessary to bring the fluid volume supporting the diaphragm within predetermined limits.

More specifically, a shaft attached to the diaphragm central area rides inside in aperture in the driven piston. A boss formed by a constricted neck portion in the stem acts as a two-way valve in cooperation with a lateral valve passageway in the piston side. The neck portions of the shaft have arteries that communicate with the hydraulic fluid in the piston chamber. The valve passageway in the piston communicates with the external reservoir via a relieved area and passageway in the piston casing. The relieved area is dimensioned so that it communicates with the piston passageway as it moves throughout the reciprocating piston cycle. The reservoir fluid is maintained at a pressure greater than the inlet pressure and less than the outlet pressure so that if the piston chamber fluid volume is insufficient during the suction stroke the spacing between the diaphragm and piston will be too small and an artery is uncovered causing fluid to flow in since the pressure in the piston chamber at that time is the same as in the pumping chamber, i.e., the inlet pressure. In a similar manner if the fluid volume is too great during the compression stroke fluid is permitted to flow out. Because the diaphragm has a smaller means diameter than the driving piston it will move further than the piston on each stroke. Thus, the boss in the two-way valve arrangement is dimensioned to avoid opening the arteries due to normal oscillation. In alternative embodiments the

two-way valve feature is retained although the stem does not ride in the piston bore.

Advantages other than those enumerated above will become apparent as the detailed description of the invention is read and understood.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional longitudinal view through one preferred embodiment of the self-compensating pump according to the invention having a rolling seal diaphragm and spring tensioning.

FIG. 2 is a cross-sectional longitudinal view through a further preferred embodiment of the self-compensating pump according to the invention having an opposing diaphragm for tensioning instead of a spring.

FIG. 3 is a cross-sectional longitudinal view through yet a further preferred embodiment of the self-compensating pump according to the invention having a relatively stiff dish diaphragm and incorporating means for adjusting pumping volume.

FIG. 4 is a cross-sectional longitudinal view through another preferred embodiment of the self-compensating pump according to the present invention having an offset piston wherein the diaphragm stem operates valving separate from the piston.

FIG. 5 is a cross-sectional longitudinal view to yet an additional preferred embodiment of the self-compensating pump according to the invention showing the applicability of the volume adjustment feature to conventional plunger type pump.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and particularly to one preferred embodiment as shown in FIG. 1, the invention comprises an enclosure that includes a hollow cylindrical piston casing 10 having a reciprocating piston 12 encased therein. Piston 12 has a central aperture or bore 23; one end of the bore is closed. The outer wall of piston 12 fits closely with the inner wall of casing 10. Piston 12 may be driven by any conventional means (not shown), for example, as by a mechanical crank, hydraulically, by electrical solenoid, or other means. Two sets of seals 50 in the inner wall of casing 10 provide a generally liquid-tight seal with the reciprocating piston 12. A cup-shaped floating head member 14 is secured centrally to a pumping diaphragm 16 by a compression cap 52 and screw 54. Diaphragm 16 is a flexible rolling diaphragm that seals the right-hand end of piston casing 10 to define a piston chamber 22. An elongated stem member 18, fixed to the inner cup portion of floating head 14, extends axially through the piston chamber 22 into the central aperture 23 of the piston 12. Stem 18 has a constricted neck portion 39 disposed adjacent a boss portion 40 at the end 38 of the stem. An O-ring 36 provides a generally liquid-tight sealing between the portion of stem 18 carrying neck 39 and boss 40 and the piston chamber 22. An artery 42 in stem 18 provides communication between piston chamber 22 and the spaces defined between the constructed neck portion 39 of stem 18 and the wall of aperture 23 and between the end 38 of the stem 18 and the end wall of aperture 23. A tension spring 20 is mounted on stem 18 between head 14 and piston 12 to provide uniform diaphragm tension to prevent diaphragm collapse or reversal. In addition, the closed end

of aperture 23 in piston 12 acts to provide diaphragm support.

Piston casing 10 has a relieved area 48 in its inner wall between the seals 50. A lateral passageway 46 in the side wall of casing 10 provides communication between the relieved area 48 and an external reservoir (not shown). Piston 12 has a lateral passageway 44 in its side wall providing communication between the centrally relieved area 48 and central aperture 23. Depending on the location of stem 18, as will be explained below, passageway 46 can communicate with the piston chamber 22 via relieved area 48, passageway 44, and artery 42.

Diaphragm 16 is sealed to the left-hand side of a pumping chamber casing 26 to define a pumping chamber 24 therewith. Casing 26 has a fluid inlet 28 with a conventional check valve 30 therein and a fluid outlet 32 with a further conventional check valve 34 therein.

The piston chamber 22 is filled with an incompressible hydraulic fluid (not shown) to maintain essentially equal pressure on either side of diaphragm 16 throughout the reciprocal cycle so that the diaphragm does not rupture.

In operation, as the piston 12 moves to the right a certain distance during the compression stroke, the floating head 14 and diaphragm 16 will move to the right a greater distance since the mean effective diameter of the head 14 and diaphragm 16 is less than the diameter of piston 12. Since equal volumes must be displaced as these members move and the piston chamber fluid is incompressible it follows that the head 14 will move a greater distance according to the relationship $L_2 = (r_1/r_2)^2 L_1$, where L_1 is the distance piston 12 moves, L_2 is the distance head 14 moves, r_1 is the piston 12 radius and r_2 is the mean effective radius of the head 14 and diaphragm 16. This effect occurs on both suction and compression strokes. Thus stem 18, fixed to the floating head 14 and diaphragm 16 center, will oscillate with respect to piston 12.

Passageway 46 is connected to a reservoir of incompressible fluid (not shown) having pressure greater than the inlet 30 pressure and less than the outlet 32 pressure. So long as the boss 40 on stem 18 is adjacent passageway 44 in the piston 12 side wall, the fluid in piston chamber 22 will not be in communication with the reservoir. However, if on a suction stroke the fluid in piston chamber 22 is not of sufficient volume, the carrying neck 39 of stem 18 will move to the left of passageway 44 to expose the artery 42 and communicate the reservoir with piston chamber 22. Since the reservoir pressure exceeds the inlet pressure (the pressure in the pumping chamber 24) during the compression stroke, the volume of fluid in piston chamber 22 will increase until the boss 40 shuts off fluid flow from passageway 44. Conversely, if during the compression stroke the fluid volume is too great, the constricted neck portion 38 will be adjacent passageway 44 to expose artery 42 and communicate the reservoir with the piston chamber 22. The fluid volume in chamber 22 will decrease since the reservoir pressure is less than the outlet pressure (the pumping chamber pressure during the compression stroke). Boss 40, the constricted neck portion 39, and the end 38 of stem 18 thus function essentially as a two-way valve. It will be apparent that piston 12 is driven so that passageway 44 is always in communication with the relieved area 48 in the piston chamber wall.

By selecting the size of boss 40 (which can be made adjustable) on stem 18 the upper and lower volume limits of the fluid in piston chamber 22 are defined, hence the maximum excursions of the floating head 14 and diaphragm 16 are defined. The particular fluid volume within chamber 22 is not, in itself, of significance. In effect, stem 18 functions to control a two-way valve in accordance with the diaphragm position.

The volume of fluid pumped by chamber 24 may be controlled by varying the stroke rate of piston 12. Alternately, by varying the length of boss 40 the pump is operable as a lost fluid device to vary the fluid volume pumped because the travel of head 14 and diaphragm 16 depends on the length of the boss.

A further alternative is described with respect to FIGS. 3, 4 and 5; by varying the end position of the piston bore the chamber volume between the end 38 of the stem and the end of the bore is varied to operate the pump as a lost fluid device.

FIGS. 2 through 5 show additional preferred embodiments of the invention. Throughout these figures elements that are essentially unchanged from FIG. 1 carry identical reference numerals; those changed but corresponding to similar elements in FIG. 1 are designated by prime markings.

FIG. 2 shows a further preferred embodiment having an opposing rolling diaphragm 17 for loading diaphragm 16 to provide tension in lieu of a spring. In order to accommodate the second diaphragm 17, the pumping chamber casing 26' is extended in length. The floating head 14' is modified to a cylindrical configuration having the two back to back rolling diaphragms 16 and 17 fixed to its opposing ends by compression caps 52 and 53 respectively. The radial ends of diaphragms 16 and 17 are sealed to the piston chamber 22 and the pumping chamber 24 by a ring 27. A slight suction for pretensioning the diaphragms is provided in the space 55 between the diaphragms. In operation, the embodiment of FIG. 2 functions otherwise in the same manner as the embodiment of FIG. 1.

Referring now to FIG. 3 wherein a preferred embodiment of the invention is shown having a dish diaphragm 16' which may be more rigid than the rolling diaphragm of the embodiments of FIGS. 1 and 2; the diaphragm can be metal, for example. A modified stem 18' having a large internal fluid capacity is connected directly to the central portion of diaphragm 16' by a pair of disc washers 14'' and 52' secured by a belt 54'. The configurations of piston casing 10', the piston chamber 22', the pumping chamber casing 26', the pumping chamber 24' and the location of inlet 28 and outlet 32 are varied slightly to accommodate the dimensions of the more rigid diaphragm.

The reciprocating piston 12' is provided with an adjustable end portion 13 that permits varying width of the lateral passageway 44 in piston 12'. End portion 13 has a set of screw threads 19 that engage screw threads 15 in piston 12'.

Stem 18' is configured as an open ended cylinder having a hollow center 56 with first and second sets of aperture, 58 and 60, in its side wall to accommodate an increased fluid flow between chamber 22 and the external reservoir. The hollow center 56 of stem 18' and its apertures 58 and 60 correspond to the artery 42 in FIGS. 1 and 2. A close fit between the outside wall of stem 18' and the inner wall of the bore in piston 12' is provided to separate the inner chamber in piston aper-

ture 23' from the piston chamber 22'. It will be apparent that any leakage is readily compensated by the reservoir and valve arrangement. A tension spring 20' extends between movable end 13 and the diaphragm end of stem 18'.

The embodiment of FIG. 3 functions basically in the same manner as the embodiments of FIGS. 1 and 2. Structurally, a rigid diaphragm replaces the rolling diaphragm, the stem employs a larger artery, and the adjustable piston end permits variations in the fluid volume pumped.

FIG. 4 shows a further embodiment, similar to FIG. 1, wherein the reciprocating piston is arranged at a right angle to the axis of the floating pumping head and stem, also demonstrating that the pumping head and stem may be located remotely from the piston. The stem and valve operate in a bore in the piston casing instead of in a bore through the piston itself. It will be apparent that the principle, function and results are substantially identical to that of the other embodiments.

The piston casing 10'' is modified to a generally inverted L shape, having a first chamber 22'' housing the floating head member 14 with attached stem 18. The end of stem 18 passes into a cylindrical aperture or bore 27 in lieu of passing into an aperture in the piston. A close fit is provided between stem 18 and the wall of bore 27. A piston chamber 64 opens into chamber 22' at a right angle. Flanged ends of piston casing 10'' and pumping chamber casing 26'' are held together by a retaining clamp 62.

Aperture 27 is closed by an adjustable end member 13' having threads 19' engaging threads in the casing 10'' so that the volume of the defined chamber 68 may be changed by inserting a driving tool into socket 21'. A lateral passageway 46' is provided between chamber 68 and an external reservoir (not shown). Thus, in the same manner as in the other embodiments, the boss 40 acts as a two-way valve in cooperation with the artery 42, the constricted neck 39, and the stem end 38. As in FIG. 3, adjustment of the end member 19° permits control of the volume of fluid pumped.

Referring now to FIG. 5, wherein a further embodiment of the invention is shown. This embodiment includes a pair of passageways to the external reservoir, each having a check valve, for use under extreme operating conditions. This modification is equally applicable to the embodiments of FIGS. 1-4. Further, this embodiment employs a conventional plunger in place of a diaphragm to demonstrate the applicability of the valve stem arrangement and variable chamber adjustment to straight plunger pumps. Also, an external indicator is provided to show the amount of fluid pumped; this modification is equally applicable to the other embodiments.

The piston casing 10''' and pumping chamber casing 26'' are substantially the same as in the embodiment of FIG. 4. An outflowing check valve 88 is provided in the passageway 46' and a further passageway 82 having an inflowing check valve 84 communicates with aperture 27. Passageways 46' and 82 can communicate with a single reservoir as described hereinbefore or alternately, two reservoirs could be used, one greater than inlet pressure; one less than outlet pressure.

A floating rigid plunger 70 provides the pumping action instead of a diaphragm. Plunger 70 has a seal 78 adjacent the inner wall of the piston casing 10''' to separate the pumping chamber 24'' from the piston cham-

ber 22''. A shaft 76 is connected axially to plunger 70 by retaining means 72. A modified stem member 18'' is connected to shaft 76 and rides with a close fit in aperture 27. Stem member 18'' is a hollow sleeve or cylinder. A tension spring 20 encircles shaft 76 between plunger 70 and the rear wall of chamber 22''.

An adjustable end member 13'' having threads 19'' mating with threads 15'' in the casing 10''' permits adjustment of the enlarged chamber 98 at the end of the bore 27. In the same manner as in the embodiments of FIGS. 3 and 4, adjustment of member 13'' changed the volume of fluid pumped. Shaft 92, an extension of shaft 76, extends through the end of member 13'' to provide an indication of the plunger 70 movement and consequently the volume of fluid being pumped. An O-ring 94 and retaining collar are provided to avoid leakage.

The self-compensating diaphragm pump thus described provides a simple, straightforward, yet effective means to overcome the problem of lost hydraulic fluid in diaphragm pumping. While setting forth the best mode known to the inventor, the embodiments of the invention described herein in the specification and shown in the drawing are only illustrative and many modifications without departing from the spirit and scope of the invention will be apparent to those of ordinary skill in this art. It will also be apparent that the invention has application in other reciprocating seal devices such as meters, hydraulic accumulators, expansion joints, and the like.

I claim:

1. Self-compensating hydraulic diaphragm apparatus comprising:

a flexible diaphragm

enclosure means in sealing relationship with said diaphragm defining a hydraulic chamber adjacent said diaphragm,

piston means in substantially fluid-tight relationship with said hydraulic chamber,

first fluid passageway means connectible to an external reservoir, and

valve means connected to said diaphragm for providing fluid communication between said hydraulic chamber and said fluid passageway means when the distance between said diaphragm and said piston means is less than a predetermined distance.

2. The combination of claim 1 wherein said valve means comprises

central passageway means through said piston means and lateral second fluid passageway means through said piston means for providing fluid communication between said central passageway means and said first fluid passageway means, and

stem means fixed to said diaphragm and extending into said central passageway.

3. The combination of claim 2 wherein said stem means comprises an elongated member having an end portion including a boss defined by a constricted neck portion with said boss positioned adjacent to said lateral second fluid passageway means, said stem means having an artery communicating between the end of said stem means, said neck portion and said hydraulic chamber.

4. The combination of claim 1 wherein said self-compensating hydraulic apparatus is pump apparatus and said enclosure means further comprises pumping chamber means adjacent the other surface of said dia-

phragm, said pumping chamber means including an inlet and an outlet.

5. The combination of claim 2 wherein said piston means comprises a piston reciprocating between predetermined limits.

6. The combination of claim 5 further comprising means for providing a tensioning force between said piston and said diaphragm.

7. The combination of claim 6 wherein said first fluid passageway means comprises a relieved area in the inner wall of said enclosure means and a lateral passageway through the wall of said enclosure means.

8. The combination of claim 6 wherein said diaphragm is a rolling seal diaphragm.

9. The combination of claim 6 wherein said diaphragm is a semi-rigid metal diaphragm.

10. The combination of claim 5 wherein said tensioning force means comprises a second diaphragm.

11. The combination of claim 6 wherein said central passageway means comprises an aperture in the direction of the axis of reciprocation of said piston.

12. The combination of claim 2 further comprising an adjustable member in a fluid tight relationship with the end of said piston means opposite said stem means for providing an adjustable central passageway volume.

13. Self-compensating hydraulic pumping apparatus comprising

a floating pumping member,

enclosure means in sealing relationship with said floating pumping member defining a hydraulic chamber adjacent said floating pumping member, reciprocating piston means in substantially fluid tight relationship with said hydraulic chamber, fluid passageway means connectible to an external reservoir,

valve means connected to said floating pumping member for providing fluid communication be-

tween said hydraulic chamber and said fluid passageway means when the distance between said floating pumping member and said fluid passageway means is less than a predetermined distance.

14. The combination of claim 13 characterized further in that said valve means connecting to said floating pumping member comprises valve means for providing fluid communication between said hydraulic chamber and said fluid passageway means when the distance between said floating pumping member and said fluid passageway means is greater than a predetermined distance.

15. The combination of claim 13 further comprising means extending through said enclosure means for indicating the position of said floating pumping member.

16. The combination of claim 13 further comprising adjustable member means for varying the volume of said hydraulic chamber.

17. The apparatus of claim 1 in which said valve means comprises a valve element physically connected to said diaphragm movable therewith and extending into said hydraulic chamber from said diaphragm, a bore receiving a portion of said element, and first and second valve portions on said valve element spaced apart from each other longitudinally of said valve element with said valve portions positioned with respect to said bore to open and close communication between said reservoir and said chamber.

18. The apparatus of claim 17 in which said bore is located in said piston means.

19. The apparatus of claim 17 in which said enclosure means includes a stationary wall facing said diaphragm, said bore is located in said wall, and said piston is mounted in said enclosure means for reciprocation along a direction generally perpendicular to said stem.

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