A piston assembly adapted for use in a diaphragm pump of the type having a piston means movable between a first and second position, a diaphragm meansmovable between a first and second position, a pumping chamber disposed on one side of said diaphragm, a transfer chamber disposed on the other side of said diaphragm and means for causing reciprocation of the piston including bias means for continuously biasing said diaphragm toward the transfer chamber and valve means responsive to the relative movement between the diaphragm and the piston for controlling the flow of fluid between a fluid source and the transfer chamber such that said valve means is closed during the power stroke of the piston and such that the valve means is open during a portion of the return stroke of the piston to replenish transfer chamber fluid lost during the power stroke.
PISTON ASSEMBLY FOR DIAPHRAGM PUMP

BACKGROUND OF THE INVENTION

The present invention relates generally to an improved diaphragm pump and more specifically, to an improved piston assembly adapted for use in such a diaphragm pump.

Diaphragm pumps which presently exist in the prior art and in which the piston assembly of the present invention is adapted for use, include a diaphragm, a pumping chamber on one side of the diaphragm containing an inlet passage and a discharge passage, a transfer chamber filled with hydraulic fluid and separated from the pumping chamber by the diaphragm, and a piston assembly defining one end of the transfer chamber and adapted for reciprocating movement between a first position and a second position to define a power stroke and a return stroke. During operation, the piston moves toward (power stroke) and away (return stroke) from the diaphragm or into and out of the transfer chamber thereby causing such reciprocating movement to be transferred, via the hydraulic fluid in the transfer chamber, to the diaphragm. As the piston moves away from the diaphragm, the diaphragm flexes away from the pumping chamber, allowing the pumping fluid to be drawn into the pumping chamber through the inlet passage. As the piston moves toward the diaphragm, the diaphragm moves accordingly, flexing toward the pumping chamber and causing the fluid in the pumping chamber to be discharged through the discharge passage.

Although most of the prior diaphragm pumps discussed above functioned sufficiently well when there was a ready supply of pumping fluid at the inlet to the pumping chamber, such pumps had a tendency to cavitate in the transfer chamber when there was not a ready supply of pumping fluid available. For example, if a full shutoff occurred in the fluid supply line, cavitation often occurred in the transfer chamber rather than in the supply line or pumping chamber, a condition which caused the transfer chamber to become over filled with hydraulic fluid and resulted in hydraulic lock on the pressure stroke. Although attempts have been made to overcome the adverse effects of a loss of pumping fluid and to prevent hydraulic lock such as that illustrated in U.S. Pat. No. 2,546,302, such attempts did not result in a satisfactory pump in that, among other things, the efficiency of the resulting pump was decreased.

Further, although many of the prior diaphragm pumps included means for replenishing the hydraulic fluid in the transfer chamber which was lost as a result of leakage during the power stroke, such means invariably comprised a spring controlled check valve which allowed hydraulic fluid to flow into the transfer chamber from a fluid reservoir when the pressure of the spring was overcome.

SUMMARY OF THE INVENTION

In contrast to the prior art, the present invention provides for a hydraulic diaphragm pump with an improved piston assembly capable of eliminating the possibility of cavitation occurring in the transfer chamber when there is a loss of pumping fluid with a minimum loss of pump efficiency and capable of replenishing the fluid in the transfer chamber without the use of a spring biased check valve.

More specifically, the piston assembly of the present invention is adapted for use in a diaphragm pump of the type having a flexible diaphragm, a pumping chamber on one side of the diaphragm and a transfer chamber on the other side of the diaphragm and includes a bias means for biasing the diaphragm continuously toward the transfer chamber and away from the pumping chamber to prevent cavitation in the transfer chamber, a piston defining one end of the transfer chamber and adapted for reciprocal movement toward and away from the transfer chamber and valve means responsive to the relative movement between the diaphragm and the piston such that during the power stroke of the piston, the valve means is closed to prevent the flow of hydraulic fluid between a hydraulic fluid reservoir and the transfer chamber and such that during the return stroke, the valve means is open only long enough to allow replenishing of the transfer chamber fluid lost during the power stroke. To accomplish this, the valve means includes the combination of a ball valve and a sliding valve arrangement wherein the ball valve is effective to prevent the flow of fluid between the fluid reservoir and the transfer chamber during the pressure stroke or whenever the pressure in the transfer chamber is greater than that in the fluid reservoir and wherein the sliding valve arrangement is effective to selectively allow flow of fluid from the reservoir into the transfer chamber to replenish that fluid lost during the power stroke but to prevent overfilling of the transfer chamber.

The present invention is advantageous over the prior art in that it includes a piston assembly which minimizes the loss of pump efficiency necessary to insure against cavitation occurring in the transfer chamber and in that it eliminates the use of a spring controlled check valve to replenish the transfer chamber fluid and insure against the possibility of overfilling the transfer chamber.

Accordingly, it is an object of the present invention to provide an improved diaphragm pump with an improved piston assembly having means to prevent cavitation from occurring on the transfer chamber side of the diaphragm with a minimum loss of efficiency in the pump.

Another object of the present invention is to provide an improved piston assembly having a valving arrangement which prevents flow of fluid between the hydraulic fluid reservoir and the transfer chamber during the power stroke and to allow replenishing of the transfer chamber fluid during the return stroke but insuring against overfilling such transfer chamber.

Another object of the present invention is to provide an improved piston assembly for use in a diaphragm pump which eliminates the need for a spring controlled check valve to replenish the transfer chamber fluid lost during the power stroke.

A further object of the present invention is to provide an improved piston assembly for a diaphragm pump wherein the valving arrangement controlling the flow of hydraulic fluid between the fluid reservoir and the transfer chamber is controlled by the combination of a ball check valve and a sliding valve arrangement responsive to the relative movement of the diaphragm assembly and the piston.

Another object of the present invention is to provide a piston assembly for a diaphragm pump having means, including bias means connected with each of said pis-
ton and diaphragm means and moveable therewith, for preventing cavitation from occurring in the transfer chamber.

These and other objects of the present invention will become apparent upon reference to the drawings, the description of the preferred embodiment and the appended claims.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross sectional view of a first embodiment of a piston assembly in accordance with the present invention with the piston and diaphragm in a first position at the completion of the return stroke under normal pumping conditions and just prior to the power stroke.

FIG. 2 is a cross sectional view of a second embodiment of the piston assembly in accordance with the present invention with the piston and diaphragm in a second position at the completion of the power stroke and just prior to the return stroke.

FIG. 3 is a plan view of a portion of the sliding valve means of the piston assembly of the present invention in a closed position corresponding to the position illustrated in FIG. 1.

FIG. 4 is a plan view of the sliding valve means of the present invention in an open position corresponding to the position illustrated in FIG. 2.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The structure of the preferred embodiment of the present invention will be described with primary reference to FIG. 1 which comprises a first embodiment. Reference will then be made to all of FIGS. 1–4 to fully describe the operation of the piston assembly of the present invention.

With reference first to FIG. 1, the piston assembly of the present invention is adapted for use in a high pressure, hydraulically balanced, multipiston diaphragm pump of the type described in applicant's co-pending application Ser. No. 203,562 filed Dec. 1, 1971 now Pat. No. 3,775,030. Generally, the apparatus of the present invention includes a piston assembly moveable between a first and second position, a diaphragm moveable between a first and second position in response to the movement of the piston assembly, and a pumping assembly which drives pumping fluid into a pumping chamber through an inlet passage and forces it out through a discharge passage in response to the movement of the diaphragm. More specifically, the piston assembly includes a relatively cylindrical piston 10 comprising an end section 11, a piston sleeve section 12 integrally formed with the end section 11 and extending downwardly therefrom as illustrated and a base section 14, separate from the end and sleeve portions 11 and 12 but moveable therewith. The base section 14 is connected with the interior surface of the piston sleeve 12 in sealing relationship by the O-ring 15. The piston 10 is adapted to slidably fit within a piston cylinder 22 which is securely fitted within the pump casing 24 and whose inner cylindrical surface approximates the outer cylindrical surface of the sleeve portion 12 of the piston to substantially prevent the flow of hydraulic fluid from the transfer chamber 25, defined in part by the interior of the piston 10, between the outer surface of the sleeve 12 and the inner surface of the cylinder 22 during reciprocation of the piston 10. It should be noted that although the fitting relationship between the sleeve portion 12 and the cylinder 22 is sufficiently tight so that reciprocating movement of the piston 10 causes corresponding reciprocal movement of the diaphragm assembly as will be discussed below, the fitting between such surfaces is loose enough to allow a limited amount of hydraulic fluid to leak from the transfer chamber 25 during the downward movement or power stroke of the piston 10. This controlled leakage serves to lubricate the sliding surfaces of the sleeve member 12 and the cylinder 22 and to aid in cooling the transfer chamber fluid when such fluid is replenished.

Associated with the piston end 11 at its upper surface is a hemispherical foot 16 which is connected with a pressure plate 18. The pressure plate 18 in turn is adapted to slidably engage the lower surface of a cam or wobble plate 21 to transfer the wobble movement of the plate 21 to the piston 10. A needle thrust roller bearing 19 is disposed between the pressure plate 18 and the cam plate 21 to reduce friction between the two surfaces. During operation of the pump, the cam plate 21, which is canted with respect to its center shaft (not shown), rotates to cause reciprocation of the piston 10. After its downward movement from the position illustrated in FIG. 1 to that illustrated in FIG. 2, the piston 10 is returned to the position of FIG. 1 by the coil spring 20 which has one end supported by the base section 14 and the other end supported by a portion of the diaphragm stop 22.

The base portion 14 of the piston 10 includes a disc shaped portion sealed at its outer peripheral edge with respect to the inner surface of the sleeve member 12 by an O-ring 15, and a hollow sleeve member 26 integrally formed with and extending at right angles with respect to the disc portion as illustrated. Formed in the center of the disc portion of the base 14 is a check valve which includes a check valve ball 35 and a valve seat 36 and which is designed to prevent the flow of hydraulic fluid from the interior of the sleeve 34 into the area 37 which is located between the end member 11 and the base 14. However, as can be seen, this check valve does not impede the flow of fluid from the area 37 into the passage 34 when the pressure in the transfer chamber 25 is less than that in the fluid reservoir 39. Thus, during the power stroke of the piston 10, the pressure of the fluid in the transfer chamber 25 and the passages 34 causes the ball 35 to seat against the seat 36 to prevent the escape of fluid from the chamber 25. However, during the return stroke of the piston 10 under normal pumping conditions, the pressure on the ball 35 is relieved allowing the fluid to flow to the area 37 into the passage 34.

Extending transversely through the lower end of the sleeve portion 26 as shown in FIG. 1 is a limiting pin 28 which is rigidly secured to the sleeve portion 26 and which extends outwardly from the sleeve portion 26 a sufficient distance to extend through a pair of elongated openings 29 in the sleeve portion 30 of the diaphragm stem and to engage and support one end of a bias means which in the preferred embodiment is a coil spring 31. Also supported and rigidly secured in one end of the sleeve member 26 is a limiting stem 32 which is an elongated member extending through the interior portion 34 of the sleeve 26 to retain the check valve ball 35 in position for engagement with its corresponding check valve seat 36 formed in the disc shaped portion of the base 14. A cylindrical port 38 is formed in
the sleeve member 26 near its lower end as viewed in FIG. 1 to form part of a sliding valve means which will be discussed in more detail below.

A diaphragm assembly is disposed at and defines one end of the transfer chamber 25 and includes a flexible diaphragm 44 disposed in a sealed relationship between the castings 24 and 41, a follower plate 42 secured to the bottom or pumping chamber side of the diaphragm 44, a diaphragm stem plate 44 disposed immediately above the diaphragm 44 and a diaphragm stem 46 extending upwardly from the stem plate 45 into the transfer chamber 25. The follower plate 42, the plate 45 and stem 46 are securely connected in the arrangement illustrated in FIG. 1 by a screw 48 extending through the plates 42 and 45, through the diaphragm 44 and into the diaphragm stem 46. The diaphragm assembly further includes a stop member or shoulder portion 22 designed to engage a portion of the upper or transfer chamber side of the diaphragm 44 as the piston 10 approaches the end of its return stroke under certain pumping conditions. It should be noted that the surface of the shoulder portion 22 which engages the diaphragm 44 is shaped to conform to the diaphragm 44 as it is operated in a position as described in more detail below, the shoulder portion 22 is positioned to limit the upward movement of the diaphragm 44 and to allow the transfer chamber 25 to be replenished with hydraulic fluid lost during the pressure stroke when the pump is operating under pressure supply conditions.

Integrally formed with the diaphragm stem member 46 and extending upwardly therefrom is a sleeve portion 30 having a pair of elongated, axially extending openings 29 diametrically opposed to each other and a flanged upper portion 49 designed to retain one end of the coil spring 31 whose other end is supported by the pin 28. As illustrated, the sleeve portion 30 is intended to extend in slideable relationship over the sleeve 26 of the piston 10 to prevent flow of hydraulic fluid between the outer surface of the sleeve 26 and the inner surface of the sleeve 30. To accomplish this, the dimensions of the inner cylindrical surface of the sleeve 30 approximate the dimensions of the outer cylindrical surface of the sleeve 26 to prevent leakage of fluid between such surfaces.

The elongated openings 29 are positioned in the sleeve 30 such that the transversely extending limiting pin 28 extends through the openings 29 to support one end of the spring 31 and such that one of the openings 29 is axially aligned with the port 38. With this arrangement, the sleeve members 26 and 30 and the openings 38 and 29 contained therein, respectively, form a sliding valve means for controlling the flow of fluid between the transfer chamber 25 and the interior 34 of the sleeve 26. For example, when the sleeves 26 and 30 are in the relative positions illustrated in FIGS. 1 and 2, the opening 29 does not communicate with the port 38 and thus flow between the chamber 25 and the passage 34 is precluded. However, if the sleeves 26 and 30 are positioned as shown in FIGS. 2 and 4, the opening 29 is in communication with the port 38 allowing fluid to flow between the chamber 25 and the passage 34. As will be discussed in more detail below during a discussion of the operation of the present invention, it will be seen that the fluid from the chamber 25 is directed via the elements 26, 29, 30 and 38, serves to replenish the transfer chamber fluid during the return stroke.

The spring 31 is disposed between the pin 28 and the upper flange 49 and serves to continuously bias the diaphragm assembly, and thus the diaphragm 44, toward the transfer chamber 25. Thus, one end of the spring 31 is supported by, and moveable with, a portion of the diaphragm assembly, while the other end of the spring 31 is supported by, and moveable with, the piston 10. The continuous force exerted on the diaphragm 44 by the spring 31 prevents cavitation from occurring in the transfer chamber 25 when there is a loss of pumping fluid. Further, as will become evident during the discussion of the operation of the present invention, the spring 31 will flex during operation of the device only when there has been a loss of fluid in the transfer chamber 25, and then, the magnitude of the deflection of the spring will be equal only to the amount of fluid lost. In this manner, the pump efficiency lost by insuring that cavitation will not occur in the chamber 25 is minimized.

Disposed immediately below the diaphragm assembly is a pumping chamber 50 and a pumping valve assembly. The pumping valve assembly includes a suction valve 51 and a discharge valve 52 each of which includes a valve seat 53 and a valve spring 56. A retainer member 58. These elements are oriented to allow fluid to flow from the supply passage 59 in through the suction valve 51 into the pumping chamber 50 and from the pumping chamber 50 out through the discharge valve 52 to the discharge conduit 60. The flow of fluid through the suction valve 51, however, will occur only if the pressure differential between the fluid in the pumping chamber 50 and the supply conduit 59 is sufficient to overcome the force of the suction valve spring 56. Of course, to maximize the efficiency of the pump, this pressure differential is intended to be as small as possible. Further, under ideal conditions, there is a continuous supply of pumping fluid to the conduit 59 and thus the pumping chamber 50, in response to the reciprocal movement of the diaphragm 44, pumping fluid is drawn into the pumping chamber 50 through the suction valve 51 during the upward or return stroke of the piston 10 and the diaphragm 44 and is forced out of the pumping chamber 50 through the discharge valve 52 during the downward or power stroke of the piston and diaphragm.

The second embodiment of the piston assembly illustrated in FIG. 2 is identical to that of FIG. 1 except for the placement of the check valve ball and the absence of the limiting stem 32 (FIG. 1). As shown in FIG. 2, the check valve ball 60 and seat 61 is formed in the end section 11 of the piston rather than the base section 14 as illustrated in FIG. 1. However, the check valve ball 60 and seat 61 of the second embodiment functions identical to the check valve ball 35 and seat 36 of FIG. 1. It should be noted that in both embodiments, the ball check valve is contained within the piston and moveable therewith, such that the ball valve tends to close by natural momentum at the beginning of each power stroke. This eliminates the need for a bias spring biasing the ball of the check valve into contact with the check valve seat.

Having now described the structure of the present invention, the operation of the piston assembly of the present invention, with general reference to FIGS. 1-4, may be understood as follows: First of all, during normal operation, where pressure in the pumping chamber 50 drops below atmospheric pressure on the suction
stroke, the piston 10 moves between a first position illustrated in FIG. 1 and a second position illustrated in FIG. 2. The downward movement of pressure stroke of the piston 10 from its first to its second position is a result of the rotation of the cam or wobble plate 21 and the transference of its resulting reciprocal movement to the piston end 11 via the pressure plate 18 and the foot member 16. The upward movement or return stroke of the piston 10 from its second position to its first position is a result of the upward force exerted on the piston by the coil spring 20 positioned between a portion of the shoulder member 22 and the lower surface of the piston base 14. Because of the spring 20, the base portion 14 is always being biased against the lower surface of the piston end 11.

Because the transfer chamber 25 is filled with hydraulic fluid, movement of the piston 10 during the power stroke from its first position (FIG. 1) to its second position (FIG. 2) causes a corresponding movement of the diaphragm 44 from its first position (FIG. 1) to its second position (FIG. 2). Of course, during the entire power stroke, the check valve portion of the valve means is closed as all of the fluid in the chamber 51 will escape through the passages 40, 37, 34 and the openings 38 and 29, returning to refill the chamber 50. This cycle is repeated, of course, for each reciprocation of the diaphragm 44 and piston 10.

Atmospheric causing fluid to flow from the reservoir 39, through the passages 40, 37, 34 and the openings 29 and 39, and into the transfer chamber 25 as the piston 10 begins its return stroke. This flow will continue into the chamber 25 until the upward movement of the piston 10, and thus the sleeve 26, reaches the point where the port 28 and the opening 29 are no longer in communication, such as is illustrated in FIGS. 1 and 3. When this occurs, the transfer chamber fluid which was lost during the power stroke will have been replenished and the diaphragm will move upwardly, with the piston 10, until the piston and diaphragm reach the position of FIG. 1, in which the diaphragm is slightly spaced from the diaphragm stop 22. In actual manufacture, the diaphragm, when in this position, is spaced from the stop 22, a distance equal to one-half the diameter of the port 38.

Under pressure supply conditions, when pumping fluid is being supplied to the pumping chamber under pressure, the transfer chamber fluid is replenished at the end of the return stroke when the diaphragm 44 hits the diaphragm stop 22. For example, under pressure supply conditions, the diaphragm 44 will then begin to move upwardly with the piston because of the force exerted by the spring 31 and the absence of sub-atmospheric pressure in the chamber 50. During this movement, there will be no flow of fluid from the reservoir to the chamber 25 even though the ports 38 and 29 are open since there is no sub-atmospheric pressure created in the chamber 25. However, when the diaphragm 44 engages the stop 22, continued upward movement of the piston 10 will cause the pressure in the chamber 25 to fall below atmospheric, drawing fluid in through the passages 40, 37 and 34 and the ports 38 and 29. Under these conditions, when the piston is in the position shown in FIG. 1, the diaphragm will be against the diaphragm stop 22 and ports 38 and 29 will be open.

It should be noted that when the piston and diaphragm assemblies are in the position illustrated in FIG. 1, the relative positions of the sleeves 26 and 30 is such that the ports 38 and 29 are closed but when the diaphragm is against the stop 22, as described above, the sleeve 26 relative to the sleeve 30 is such that ports 29 and 38 are open. Such change in relationship of diaphragm to piston results in a slight decrease in the volume of the transfer chamber 25. Thus, the sliding valve means will be in an open position whenever the volume of the transfer chamber 25 is less than the volume of such chamber when the piston and diaphragm assemblies are in their first position shown in FIG. 1. It should also be noted that the sliding valve means may be open during a portion of the power stroke of the piston 10 due to the leakage of transfer chamber fluid, however, as stated above, the check valve means will be closed during the entire power stroke to prevent flow between the reservoir 39 and the chamber 25.

As the piston 10 and the diaphragm 44 move down during the power stroke, the pumping fluid which is in the pumping chamber 50 is forced out through the discharge valve 52 into the discharge conduit 60. During the upward movement or return stroke of the piston 10 and the diaphragm 44, pumping fluid is drawn into the pumping chamber 50 from the fluid supply conduit 59 through the suction valve 51 to refill the chamber 50. This cycle is repeated, of course, for each reciprocation of the diaphragm 44 and piston 10.
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Under ideal or pressure supply conditions where there is a ready supply of pumping fluid in the conduit 59, the piston 10 and the diaphragm 44 continue to reciprocate as explained above, with no cavitation occurring either in the transfer chamber 25 or in the pumping chamber 50. However, as is sometimes the case, there is a loss of pumping fluid in the conduit 59. The result is that the diaphragm 44 draws a vacuum in the pumping chamber 50 during its upward movement. When this happens, there is also a tendency for cavitation to occur in the transfer chamber 25 due to the upward movement of the piston as well as in the pumping chamber 50. However, because of the spring member 31, the diaphragm assembly is continually biased away from the pumping chamber 50 and toward the transfer chamber 25. Therefore, cavitation in the transfer chamber 25 will be prevented under such conditions. Although the exact size of the spring 31 is not critical, it must be strong enough to maintain sufficient pressure on the diaphragm assembly and chamber 25 to keep the diaphragm 44 convex, as shown in FIG. 1, and to prevent cavitation. In the preferred embodiment, it has been determined that the spring 31 should be great enough to develop a pressure of three to four pounds per square inch on the transfer chamber side of the diaphragm.

Although the description of the preferred embodiment has been quite specific, it is contemplated that various changes and modifications could be made to the structure of the preferred embodiment without deviating from the spirit of the present invention. Thus, it is intended that the scope of the present invention be dictated by the appended claims rather than by the description of the preferred embodiment.

1. A piston assembly for use in a diaphragm pump having a piston adapted for reciprocal movement from a first to a second position defining a power stroke and from said second to said first position defining a return stroke, a diaphragm movable between first and second positions, a pumping chamber on one side of said diaphragm, a transfer chamber on the other side of said diaphragm having a volume defined, in part, by the relative positions of said piston and said diaphragm, a source of hydraulic fluid means forming an inlet for hydraulic fluid to said transfer chamber, said fluid in said transfer chamber serving to transfer motion of said piston to said diaphragm, and means for reciprocating the piston, said piston assembly comprising:

   bias means movable with said piston for continuously biasing said diaphragm toward said piston;

   diaphragm stop means for limiting the movement of said diaphragm away from said pumping chamber, and defining the first position of said diaphragm when said diaphragm is in contact therewith;

   valve means responsive to relative movement between said diaphragm and said piston for controlling the flow of hydraulic fluid from said hydraulic fluid source into said transfer chamber such that said valve means is closed whenever the pressure in said transfer chamber is greater than the pressure in said hydraulic fluid source and such that said valve means is open whenever the pressure in said transfer chamber is less than the pressure in said hydraulic fluid source and the volume of said transfer chamber is less than the volume thereof when each of said piston and said diaphragm is in its first position.

2. The piston assembly of claim 1 wherein said piston and diaphragm are coaxial and said bias means has one end connected with said diaphragm means and the other end connected coaxially with said piston means for movement therewith.

3. The piston assembly of claim 2 wherein said bias means is a coil spring.

4. The piston assembly of claim 3 wherein said coil spring exerts a force on said diaphragm which is great enough to develop a pressure of 3 to 4 p.s.i. on the transfer chamber side of said diaphragm.

5. The piston assembly of claim 1 wherein said valve means includes a check valve means and a sliding valve means.

6. The piston assembly of claim 5 wherein said check valve means is effective to prevent flow of fluid from said hydraulic fluid source into said transfer chamber whenever the pressure in said transfer chamber is greater than the pressure in said hydraulic fluid source, and wherein said sliding valve means is open when the volume of said transfer means is less than the volume of said transfer chamber when each of said piston and said diaphragm is in its first position.

7. The piston assembly of claim 6 wherein said check valve means is effective to prevent flow of fluid from said hydraulic fluid source into said transfer chamber during said power stroke.

8. The piston assembly of claim 7 wherein said sliding valve means includes a first sleeve member connected with said piston and a second sleeve member connected with said diaphragm with one of said first and second sleeve members adapted for slidable movement within the other, each of said sleeve members including a port such that when said ports are in communication with each other said sliding valve means is open and when said ports are not in communication with each other said sliding valve means is closed.

9. The piston assembly of claim 8 wherein said first sleeve member is adapted for slidable movement within said second sleeve member.

10. The piston assembly of claim 9 wherein said check valve means is positioned between said hydraulic fluid reservoir and said sliding valve means.

11. The piston assembly of claim 10 wherein said piston and diaphragm are coaxial and said bias means has one end connected with and moveable with said diaphragm means and the other end connected coaxially with and moveable with said piston means.

12. The piston assembly of claim 11 wherein said bias means has one end connected with and moveable with said first sleeve member and the other end connected with and moveable with said second sleeve member.

13. The piston assembly of claim 7 wherein said check valve means is a ball valve contained within said piston and moveable therewith such that said ball valve tends to close by natural momentum at the beginning of each power stroke.

14. The piston assembly of claim 1 wherein said stop means limits the movement of said diaphragm near the completion of the return stroke, thereby removing pressure forces from said diaphragm and permitting said transfer chamber to be refilled.