

[54] **DIAPHRAGM PUMP**

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[58] Field of Search.....**417/395, 311, 413, 383;**
137/469; 92/102, 98 R

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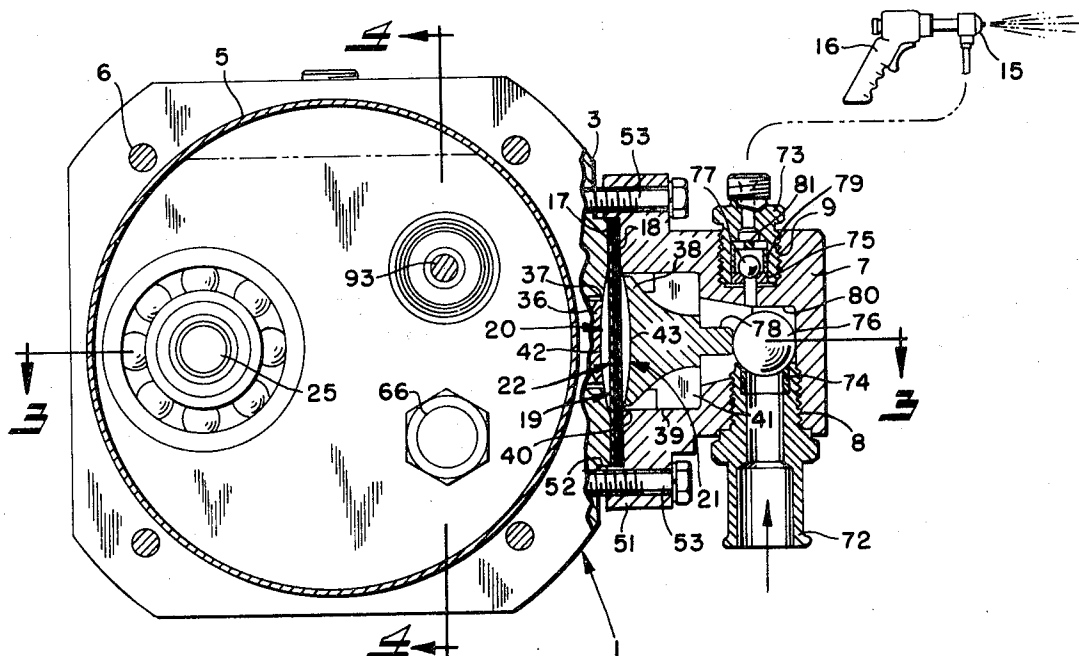
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[57] **ABSTRACT**

A diaphragm pump including a variable area relief valve for the working fluid which permits the pump to operate at reduced pressure when a peak load is reached during standby operation to reduce power requirements, allow the pump to run cooler, and reduce wear of parts. The walls of the pumping and working chambers are desirably shaped to conform to the natural form taken by the diaphragm during flexing for increased diaphragm life, and relatively small ring-shaped flow passages of different diameters desirably communicate with such chambers to reduce the change of diaphragm extrusion into the flow passages and diaphragm rupture. The diaphragm itself may consist of multiple unconnected layers all of the same size for increased life, and radially spaced cooperating seal ridges may be provided on the diaphragm clamping faces to prevent extrusion of the diaphragm material into the center during uniform clamping of the diaphragm around its periphery. A molded diaphragm having a built-up center portion may also be used for increased life.

15 Claims, 6 Drawing Figures



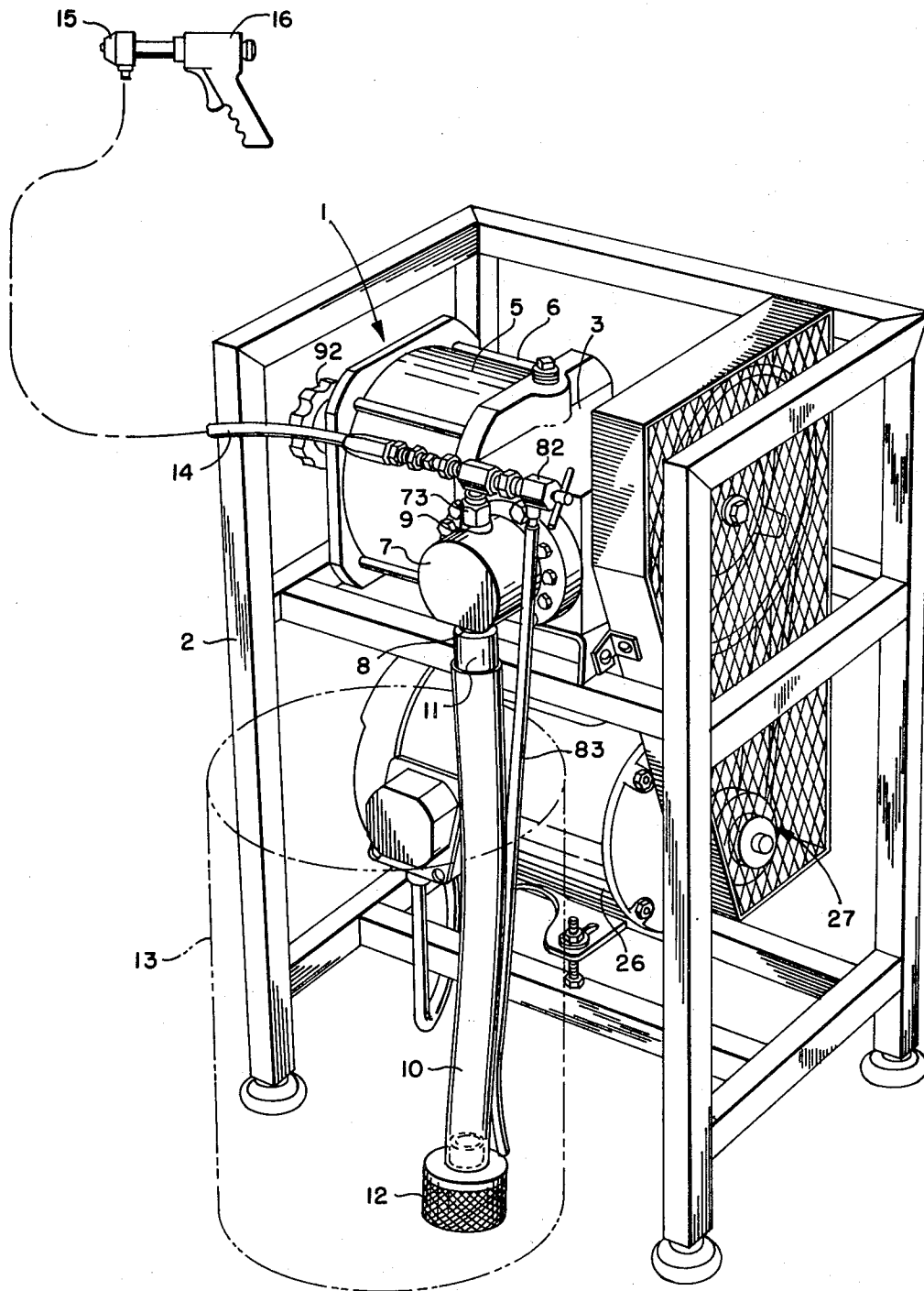


Fig. 1

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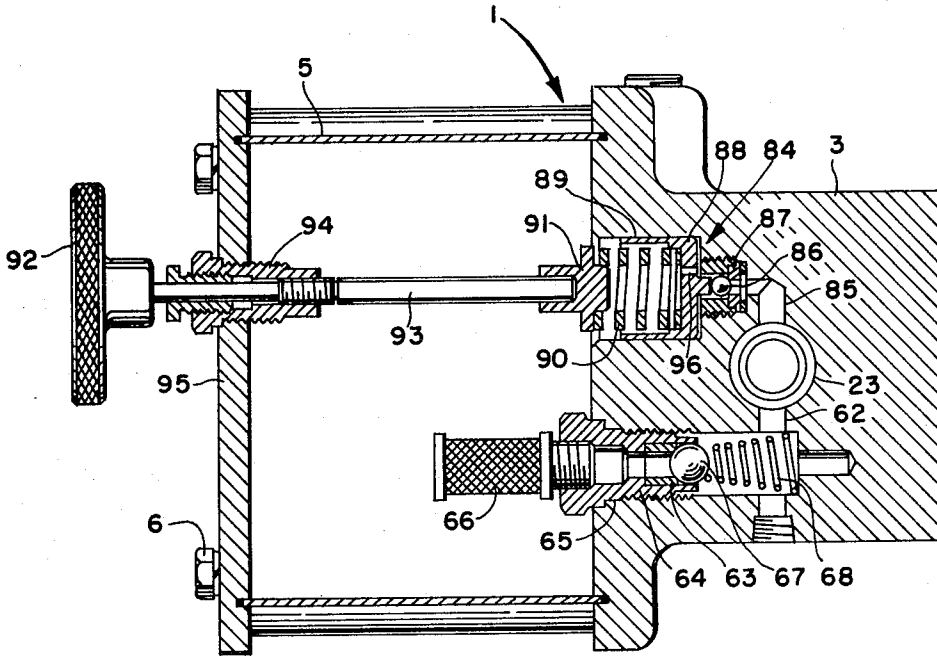


FIG. 4

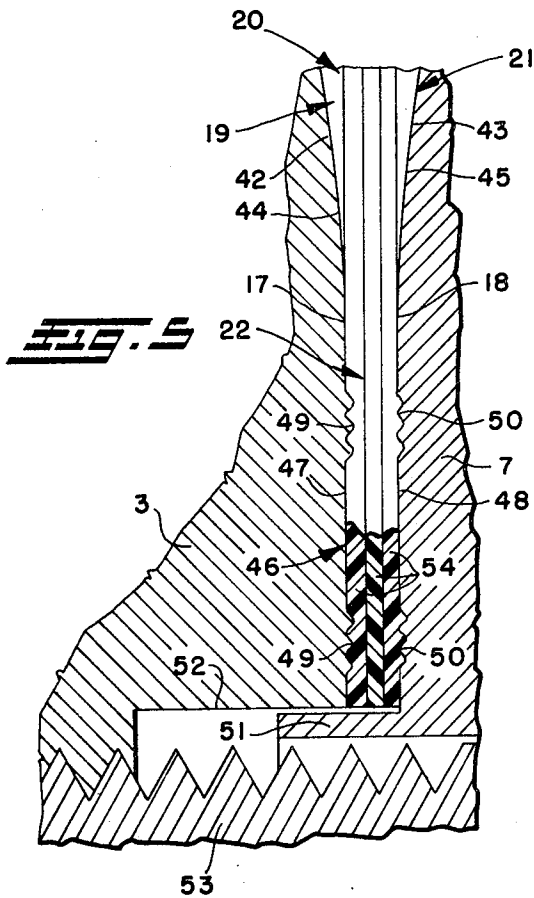


FIG. 5

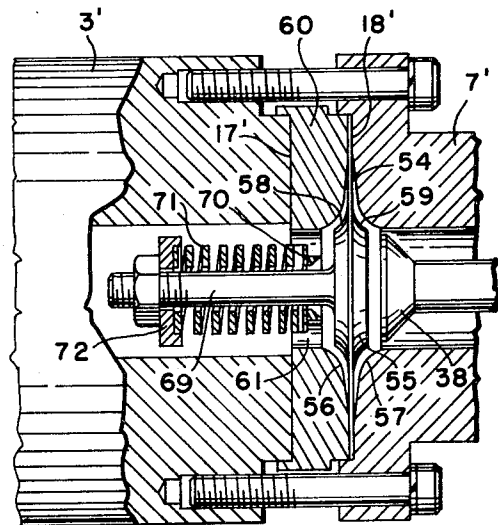


FIG. 6

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DIAPHRAGM PUMP

BACKGROUND OF THE INVENTION

This invention relates generally as indicated to a diaphragm pump, and more particularly, to certain improvements in diaphragm pumps, particularly for use in the intermittent pumping or spraying of paint and other fluids under relatively high pressure.

The usual diaphragm pump consists of a cavity in which is contained a flexible diaphragm dividing the cavity into two separate chambers, one for the working fluid, usually oil, and the other for the fluid to be pumped. The working fluid chamber communicates with a cylinder in which is reciprocally mounted a piston. During the intake stroke of the piston, a partial vacuum is exerted on the working fluid, causing the diaphragm to flex in a direction creating a partial vacuum in the pumping chamber, which draws fluid to be pumped into the pumping chamber through an inlet valve. On the discharge stroke, the piston exerts pressure on the working fluid which causes the diaphragm to flex in the reverse direction, applying pressure to the fluid in the pumping chamber for discharge through an outlet valve.

As long as the outlet valve is free to open, the pump will continue to discharge pumping fluid from the pumping chamber on the discharge stroke of the piston and draw fluid into the pumping chamber on the intake stroke. However, when pumping certain fluids such as paint, the discharge is independently controlled by actuation of a spray gun or other device connected to the pump outlet to permit the flow from the pump to be interrupted by the operator while the pump continues to operate. This places an increased load on the pump and causes a buildup of the working fluid pressure to the setting of a relief valve. The result is that the power requirements for the pump are greater during standby operation than during discharge, which not only makes the pump less efficient, but necessitates the use of a larger motor to drive the pump and requires increased cooling for the pump. Moreover, the wear on parts is greater during standby operation.

Another problem oftentimes encountered with diaphragm pumps is premature failure of the diaphragm. Increased diaphragm life has been obtained by using better materials for the diaphragm and also by providing better support for the diaphragm during flexing, but to obtain significantly increased diaphragm life has required the use of relatively complicated and expensive diaphragm assemblies that are much more difficult and expensive to manufacture and assemble. Moreover, the usual diaphragm pump is relatively large in size, making it difficult to transport, and even the less reliable pumps are relatively complex and expensive to manufacture.

SUMMARY OF THE INVENTION

With the foregoing in mind, it is a principal object of this invention to provide a diaphragm pump which utilizes considerably less power during standby operation while the pump is running but not discharging fluid, thereby greatly increasing the efficiency of the pump.

Another object is to provide a diaphragm pump which requires less cooling than previous known pumps of the same general size and type.

Still another object is to provide a diaphragm pump in which the various parts are subjected to less wear during standby operation.

Another object is to provide such a diaphragm pump with a novel chamber configuration to provide better support for the diaphragm during flexing for increased life.

Another object is to provide such a diaphragm pump with improved clamping for the diaphragm to obtain uniform clamping pressure around the periphery of the diaphragm and prevent extrusion of the diaphragm material into the center to avoid wrinkles and creases in the diaphragm which create points of high stress concentration.

Yet another object is to provide such a diaphragm pump with a relatively inexpensive diaphragm which has substantially increased diaphragm life.

Another object is to provide such a diaphragm pump which is highly reliable and yet is relatively simple and compact for ease of manufacture.

These and other objects of the present invention may be achieved by providing the diaphragm pump with a variable area relief valve for the working fluid which permits the pump to operate at reduced pressure after a peak pressure has been attained for increased efficiency, reduced wear of parts, and less required cooling. The walls of the pumping and working fluid chambers are desirably of a generally spherical shape which conform closely to the natural form taken by the diaphragm during flexing for increased diaphragm life, and one or both passages to the chambers may be ring-shaped and of relatively small size to prevent extrusion of the diaphragm material into the passages.

The diaphragm itself desirably consists of two or more unconnected layers of Mylar or other suitable material, all the same size, and all uniformly clamped around their outer peripheries between two clamping faces having cooperating seal ridges thereon which prevent extrusion of the diaphragm material toward the center to eliminate wrinkles or creases in the diaphragm which create high points of stress concentration. The advantage in using multiple layers for the diaphragm is that each layer may be made relatively thin for increased flexibility, but together they provide a sufficient combined thickness for effective clamping and resistance to extrusion into the flow passages to the chambers. The diaphragm layers are desirably unconnected except at their peripheries where they are uniformly clamped as aforesaid, but silicon grease may be used between the diaphragm layers to enhance sliding motion therebetween. Alternatively, the diaphragm may be molded in a single piece with greater thickness at the center portion for engagement with the flow passages to increase diaphragm life.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention, these being indicative, however, of but a few of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIG. 1 is an isometric view of a preferred form of diaphragm pump constructed in accordance with this invention shown mounted on a suitable support stand provided therefor;

FIG. 2 is a transverse section through such a diaphragm pump, taken on the plane of the line 2—2 of FIG. 3;

FIG. 3 is a horizontal section through the pump of FIG. 2, taken on the plane of the line 3—3 thereof;

FIG. 4 is a vertical section through the pump of FIG. 2, taken on the plane of the line 4—4 thereof;

FIG. 5 is an enlarged fragmentary horizontal section of a portion of the diaphragm and clamping mechanism of FIG. 3; and

FIG. 6 is a fragmentary horizontal section through a modified form of diaphragm pump constructed in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now in detail to the drawings, and first especially to FIG. 1, there is illustrated by way of example a preferred form of diaphragm pump 1 in accordance with this invention shown mounted on a suitable support stand 2. Preferably, the diaphragm pump 1 consists of three main parts, the main housing 3 which contains the piston and drive mechanism to be subsequently described, a reservoir 5 for working fluid such as oil which is clamped to one face of the main housing 3 using suitable tie rods 6, and a pumping fluid housing 7 clamped to another face of the main housing and containing inlet and outlet ports 8 and 9 for the fluid to be pumped. An intake line 10 having one end 11 attached to the inlet port 8 and a strainer 12 in the other end to keep out foreign matter may be inserted into a suitable container for the fluid to be pumped such as the five-gallon drum 13 shown in phantom lines in FIG. 1, and a hose 14 may be used to connect the outlet port 9 to the nozzle 15 of a spray gun 16 or other device for controlling the discharge of fluid from the pump.

Referring further to FIG. 1 and also to FIGS. 2 through 5, the details of construction and operation of the diaphragm pump 1 will now be described. As clearly shown in FIGS. 2, 3 and 5, the abutting faces 17 and 18 of the main housing 3 and pumping fluid housing 7 are shaped to define a cavity 19 therebetween which is divided into two separate chambers 20 and 21 by a diaphragm 22 clamped at its outer periphery in a manner to be more fully described hereafter. A longitudinal bore 23 within the main housing 3 communicates with the chamber 20 and contains a piston 24 (see FIG. 3) which is reciprocated back and forth by rotation of a crank shaft 25 suitably journaled within the main housing 3. The crank shaft 25 is driven by a suitable drive motor 26 which may be mounted on the support stand 2 beneath the diaphragm pump 1 and connected to the crank shaft as by the pulley and belt drive 27 illustrated in FIG. 1. On the crank shaft 25 is an eccentric portion 28 which has a cam 29 mounted thereon, and the piston 24 is maintained in engagement with the cam 29 by a spring 30 interposed between the outer end of the piston and a backup member 31 mounted in the bore 23 in longitudinal spaced relation from the piston.

The backup member 31 is retained in place within the longitudinal bore 23 by a transverse pin 32 passing through the body portion 33 thereof, and flats 34 are provided on such body portion which permit flow of a suitable working fluid such as oil therepast during reciprocating of the piston 24. Attached to the forward end of the body portion 33 adjacent the bore opening 35 to the chamber 20 is a head portion 36 having an outer diameter slightly less than the diameter of the bore opening 35 to provide a relatively small width annular ring-shaped passage 37 between the bore 23 and chamber 20 which prevents extrusion of the diaphragm material into the passage and minimizes the amount of cutting edges of the passage for the required flow area.

A backup member 38 is also disposed in an annular recess 39 in the face 18 of the pumping fluid housing 7 which is of a diameter slightly less than the diameter of the recess adjacent the chamber 21 opening to provide a relatively small width annular ring-shaped passage 40 between the chamber 21 and interior of the pumping fluid housing 7 for communication with both the inlet and outlet ports 8 and 9 through peripheral slots 41 in the base of the backup member 38. Once again, the size of the ring-shaped passage 40 is sufficiently small to prevent extrusion of the diaphragm material into the passage during flexing, and such ring-shaped passage also provides the greatest flow area for the amount of cutting edges. Moreover, by making the ring-shaped passage 40 in the pumping fluid housing 7 of a diameter greater than the diameter of the ring-shaped passage 37 in the main housing 3, the amount of flow area is increased to permit pumping of more viscous fluids through the pumping chamber and to offset the areas of stress concentration on opposite sides of the diaphragm.

The walls of the housing faces 17 and 18 which comprise the chamber walls 42 and 43 are generally spherical in shape to conform to the natural form or shape taken by the diaphragm 22 when flexed, and the end walls of the backup members 33 and 38 are of a corresponding shape to provide a continuation of the curvature of the chamber walls 42 and 43 for proper support of the diaphragm during flexing for increased life. For a 3 inch diameter diaphragm, the radius of curvature of the chamber walls 42 and 43 is desirably approximately 4.25 inch with a maximum depth of approximately 0.144 inch at the center, and the outer edges 44 and 45 of the chamber walls desirably have a reverse radius of approximately 1.25 inch struck from a center located radially outwardly from the axial center of the sphere approximately 1.25 inch to provide a gradual transformation region to the peripheral sealing zone 46 for the diaphragm (see FIG. 5). By making the profile of the chamber walls 42 and 43 conform to the natural form taken by the diaphragm when flexed and providing a gradual transformation region around the center peripheries of the chamber walls out to the sealing zone, folds or creases in the diaphragm material are substantially eliminated during flexing, thus avoiding high points of stress concentration which further increases diaphragm life.

As best seen in FIG. 5, the diaphragm sealing surfaces 47 and 48 of the main housing and pumping fluid housing faces 17 and 18 outwardly of the chambers 20 and 21 are desirably provided with two sets of radially

spaced circumferential seal ridges 49 and 50 which engage the outer periphery of the diaphragm 22 during clamping of the diaphragm therebetween to prevent extrusion of the diaphragm material into the center, thus avoiding additional wrinkles or creases in the diaphragm material during assembly which would create high points of stress concentration as aforesaid. Preferably, each set of sealing ridges 49 and 50 consists of three ridges, each approximately 0.005 inch high and approximately 0.015 inch wide, with approximately 1 inch clearance between sets.

Accurate positioning of the diaphragm 22 with respect to the pumping chamber 21 is obtained by providing a flange 51 around the periphery of the sealing surface 48 which has an inner diameter slightly greater than the outer diameter of the diaphragm for receipt therein, and the main housing 3 has an annular shoulder 52 which is of a diameter slightly less than the inner diameter of the flange 51 for accurate centering of the pumping fluid housing 7 and diaphragm 22 with respect to the working fluid chamber 20. Uniform clamping pressure is applied to the outer periphery of the diaphragm 22 by using a plurality of uniformly spaced fasteners 53 extending through the housing flange 51 into the main housing 3 outwardly of the shoulder 52.

The diaphragm 22 itself desirably consists of two or more layers 54 of suitable material such as Mylar all of the same diameter and thickness and unconnected to permit free movement relative to each other except at their outer peripheries where they are clamped together as aforesaid. Silicon grease may be used between the diaphragm layers to enhance sliding motion between layers during flexing. For a 3 inch diameter diaphragm, each layer is desirably approximately 0.015 inch in thickness.

Using multiple diaphragm layers permits the diaphragm to be made relatively thin for increased flexibility while still providing a sufficient combined thickness for effective clamping and resistance to extrusion of the diaphragm into the passages communicating with the chambers. In actual tests, the longest life obtained using a single layer diaphragm of uniform thickness was approximately 120 hours, but most failed in less than 50 hours. However, when two layers of diaphragm material of the same size were used, the life of the diaphragm was increased to approximately 343 hours, and when three layers of the same size diaphragm material were used, the life was extended to approximately 1205 hours before failure.

While Mylar is preferred as the diaphragm material, it will be apparent that other materials which have the required high flexure life, can withstand chemical attack from paint, solvent, water, or other fluids being pumped, and is sufficiently erosion-resistant to withstand any abrasiveness that the material may exhibit as from the pigments in paints. Nylon 11 and polypropylene are examples of other materials which may be used, and these latter materials have the advantage that they may be molded to provide a diaphragm 54 with an axially thickened center portion 55 for increased strength to reduce the chance of rupture as shown in FIG. 6. Of course, the diaphragm 54 will not flex in the built-up center portion 55, and accordingly there is no need to make the chamber walls

56 and 57 of spherical shape. However, the edges 58 and 59 of the axially thickened center portion 55 are desirably rounded and portions of the chamber walls 56 and 57 are correspondingly rounded for engagement thereby to limit maximum flexing of the diaphragm. Moreover, one or both of the backup members 33 and 38 may be eliminated and chamber plates 60 used in place of the backup members between the faces 17' and 18' of the main housing 3' and pumping fluid housing 7'. Holes 61 in the chamber plate 60 provide for flow into and out of the associated chamber.

Referring once again to FIGS. 3 and 4, a suitable supply of working fluid such as oil is maintained in the working fluid chamber 20 and associated bore 23 by providing a passage 62 in the main housing 3 which communicates the bore 23 with the oil reservoir 5. Within the passage 62 is an oil inlet seat 63 retained in place by an oil inlet body 64 threaded into the passage inlet 65 from the reservoir 5. A strainer 66 threaded into the inlet body 64 prevents any undesirable foreign matter from entering the passage 62 with the oil, and a check valve ball 67 urged into engagement with the seat 63 by a spring 68 only permits fluid flow into the bore 23 during retraction of the piston 24 after a sufficient partial vacuum has been created to deflect the diaphragm 22 against the working fluid chamber wall 42 for make up of any fluid lost due to leakage to prevent cavitation.

If a molded diaphragm 54 with built-up center portion 55 is used such as shown in FIG. 6, a center post 69 may be provided thereon which extends through a central opening 70 in the chamber plate 60 for mounting of a return spring 71 between the chamber plate and a spring retainer 72 on the outer end of the center post 69 to aid in flexing the diaphragm 54 into engagement with the working fluid chamber wall 56 during retraction of the piston. Otherwise, the details of construction and operation of the diaphragm pump 1' shown in FIG. 6 may be the same as the pump of the FIGS. 1-5 embodiment, and the same reference numerals followed by a prime symbol are used to identify the parts.

In FIG. 2, inlet and outlet valve bodies 72 and 73 are shown threadedly received in the inlet and outlet ports 8 and 9 of the pumping fluid housing 7, with valve seats 74 and 75 in the valve bodies for inlet and outlet check valves 76 and 77. The inlet check valve 76 is guided during its movement toward and away from its associated seat 74 by a projection 78 on the inner end of the backup member 38, and a guide sleeve 79 is contained within the outlet valve body 73 for guiding the movements of the outlet valve 77 toward and away from its seat 75. Inward movement of the inlet valve 76 away from its seat 74 is limited by engagement with the interior wall 80 of the pumping fluid housing 7, whereas outward movement of the outlet valve 77 away from its seat 75 is limited by a valve ball stop 81 contained within the outlet valve body 73.

In operation, retraction of the piston 24 causes the diaphragm 22 to deflect toward the working fluid chamber wall 42, which creates a partial vacuum in the pumping chamber 21, causing the outlet valve 77 to be seated and the inlet valve 76 to open for drawing pumping fluid into the pumping chamber. On the discharge stroke, the diaphragm 22 is flexed in the reverse direction toward the pumping chamber wall 43 which

creates a pressure on the pumping fluid forcing the inlet valve 76 closed and opening the outlet valve 77 for discharge of the pumping fluid under pressure through the outlet port 9. During initial startup of the pump, a valve 82 connected to the outlet valve body 73 may be opened to permit circulation of the pumping fluid through the pumping chamber 21 and back to the container 13 through a bleed line 83 (see FIG. 1) for removal of air from the system, after which the valve 82 is closed and the pump is ready to discharge pumping fluid through the hose 14 leading to the spray nozzle 16 or other suitable device.

As long as the spray nozzle 16 is open, the pump will continue to discharge pumping fluid at a relatively constant pressure. However, as soon as the spray nozzle 16 is closed, the pressure will build up within the pump until relieved by opening of the pressure relief valve 84, shown in detail, in FIG. 4, which dumps the excessive working fluid acted on by the piston back to the oil reservoir 5 through a branch passage 85 in the main housing 3. The usual pressure relief valve for a diaphragm pump is a conventional check valve which opens only when the pressure reaches a predetermined level above the desired pumping pressure, and consequently a diaphragm pump ordinarily operates under a greater load during standby operation than when the pump is discharging fluid. This necessitates the use of a larger motor than would be required simply to discharge pumping fluid from the pump, and of course the power requirements for the pump are greater during standby operation, and greater cooling is required. There is also greater wear on the pump parts during standby operation.

To overcome these various drawbacks, the relief valve 84 of the present invention includes a relatively small diameter ball check valve 86 which is urged against its seat 87 by a larger diameter relief valve piston 88 contained in a recess 89 in the main housing 3 which is pressed against the check valve 86 by a spring 90 interposed between the piston 88 and an adjustable stop 91. When the relief valve 84 is closed, the oil pressure within the passage 85 in the main housing 3 initially only acts on the relatively small exposed area of the ball check valve 86. However, as soon as a sufficient pressure level is attained to open the ball check valve 86, the fluid passing therethrough also acts on the relatively larger area of the relief valve piston 88 to maintain the valve open at reduced pressures for providing reduced pressure in the pumping chamber 20 during standby operation. Accordingly, less power is required to operate the pump during standby operation, since the pump does not operate at peak loads for any length of time. In actual tests, the power requirements to operate a pump constructed in accordance with the present invention during standby operation were approximately one-third of that required to operate the pump during discharge. Actual values under typical service conditions were 900 watts during discharge and 325 watts during standby.

Adjustment of the spring 90 pressure acting on the relief valve piston 88 may be made by rotation of a pressure control knob 92 exteriorly of the oil reservoir 5 which is connected to the relief valve spring stop 91 by a control screw 93 having threaded engagement with a pressure control sleeve 94 fixed to the oil reservoir end plate 95.

The fluid pressure acting on the relief valve piston 88 is continuously bled to the reservoir 5 through a bleed passage 96 therein, and when the pressure acting on the relief valve piston 88 drops below a predetermined low level, the ball check valve 86 is reseated by the pressure applied by the spring 90. The ball check valve 86 remains closed until the pressure builds up once again to a predetermined high level which varies with the setting of the relief valve spring 90.

Since the pump 1 is only under maximum load for a short period of time, a larger motor is not required to operate the pump during standby, and less cooling is also required during standby. Moreover, there is less wear of parts during standby operation, and the power requirements are also less.

While certain representative embodiments and details have been shown for the purpose of illustrating the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of the present invention.

We, therefore, particularly point out and distinctly claim as our invention:

1. A diaphragm pump comprising a housing, a cavity within said housing, a flexible diaphragm dividing said cavity into two separate chambers, means for forcing a working fluid into and out of one of said chambers to cause said diaphragm to flex in opposite directions for respectively decreasing and increasing the volume of the other of said chambers for pumping fluid into and out of said other chamber, and relief valve means opened in response to the pump pressure reaching a predetermined high level to prevent increased pressure build up within said pump, said diaphragm consisting of at least two layers of flexible material, with silicon grease applied to said diaphragm between said layers to enhance sliding of said layers relative to each other during flexing of said diaphragm, and means for clamping said layers together radially outwardly of said cavity, said layers otherwise being unconnected.

2. The pump of claim 1 wherein said diaphragm consists of three layers of such flexible material.

3. The pump of claim 1 wherein said diaphragm material is Mylar.

4. The pump of claim 1 wherein each layer of diaphragm material is approximately 0.015 inch thick.

5. A diaphragm pump comprising a housing, a cavity within said housing, a flexible diaphragm dividing said cavity into two separate chambers, means for forcing a working fluid into and out of one of said chambers to cause said diaphragm to flex in opposite directions for respectively decreasing and increasing the volume of the other of said chambers for pumping fluid into and out of said other chamber, and relief valve means opened in response to the pump pressure reaching a predetermined high level to prevent increased pressure build up within said pump, said diaphragm consisting of at least one layer of flexible material of substantially uniform thickness, the walls of said chamber being of substantially spherical shape which conforms to the natural shape taken by said diaphragm during flexing, central openings in said chamber walls communicating with said chambers, and a backup member disposed in at least one of said openings providing a relatively small ring-shaped passage in communication with one of said chambers, said backup member being shaped to pro-

vide a continuation of the curvature of the wall of said one chamber.

6. The pump of claim 5 further comprising inlet and outlet check valves and associated seats in said housing for passage of pumping fluid into and out of said other chamber, said backup member being disposed in the opening in the chamber wall of said other chamber and having a projection on the inner end for guiding movement of said inlet check valve during movement toward and away from its associated seat.

7. The pump of claim 5 wherein the outer edges of said chamber walls have a reverse radius to provide a gradual transformation region between said clamping means and the spherical contour of said chamber walls.

8. The pump of claim 5 further comprising means for maintaining said relief valve means open until the pump pressure drops to a predetermined level substantially less than the pressure level at which said relief valve means originally opened, said relief valve means comprising a ball check valve, and said means for maintaining said relief valve means open comprising a relief valve piston, spring means urging said relief valve piston into engagement with said ball check valve for closing said ball check valve, said relief valve piston being subjected to the fluid pressure in said pump after opening of said ball check valve to reduce the amount of pressure required to keep said ball check valve open.

9. The pump of claim 8 wherein the effective area of said relief valve piston is substantially greater than the area of said ball check valve acted on by fluid pressure, and said relief valve piston has a bleed passage therein for bleeding of the fluid pressure acting on said relief valve piston to a reservoir.

10. The pump of claim 8 further comprising means for adjusting the tension of said spring means to vary the pressure setting of said ball check valve.

11. A diaphragm pump comprising a housing, a cavity within said housing, a flexible diaphragm dividing said cavity into two separate chambers, means for forcing a working fluid into and out of one of said chambers to cause said diaphragm to flex in opposite directions for respectively decreasing and increasing the volume of the other of said chambers for pumping fluid into and out of said other chamber, and relief valve means opened in response to the pump pressure reaching a

predetermined high level to prevent increased pressure build up within said pump, said diaphragm consisting of at least one layer of flexible material of substantially uniform thickness, the walls of said chambers being of substantially spherical shape which conforms to the natural shape taken by said diaphragm during flexing, said housing including ring-shaped annular flow passages communicating with each of said chambers, said flow passages being of a relatively narrow width to prevent extrusion of the diaphragm material into said flow passages during flexing.

12. The pump of claim 11 wherein said ring-shaped flow passages are coaxial but radially offset to distribute the stresses on opposite sides of said diaphragm.

13. The pump of claim 11 further comprising clamping means for uniformly clamping said diaphragm radially outwardly of said chambers, said clamping means comprising a pair of substantially radial surfaces having annular sealing ridges thereon for engagement with the outer periphery of said diaphragm, and a plurality of circumferentially spaced fasteners for drawing said radial surfaces into clamping engagement with said outer periphery of said diaphragm.

14. The pump of claim 13 wherein there are two sets of sealing ridges, each set consisting of a plurality of said sealing ridges closely spaced apart, and each set being further spaced apart.

15. The pump of claim 11 further comprising means for maintaining said relief valve means open until the pump pressure drops to a predetermined level substantially less than the pressure level at which said relief valve means originally opened, said relief valve means comprising a ball check valve, and said means for maintaining said relief valve means open comprising a relief valve piston, spring means urging said relief valve piston into engagement with said ball check valve for closing said ball check valve, said relief valve piston being subjected to the fluid pressure in said pump after opening of said ball check valve to reduce the amount of pressure required to keep said ball check valve open, the effective area of said relief valve piston being substantially greater than the area of said ball check valve acted on by fluid pressure, and said relief valve piston having a bleed passage therein for bleeding of the fluid pressure acting on said relief valve piston to a reservoir.

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