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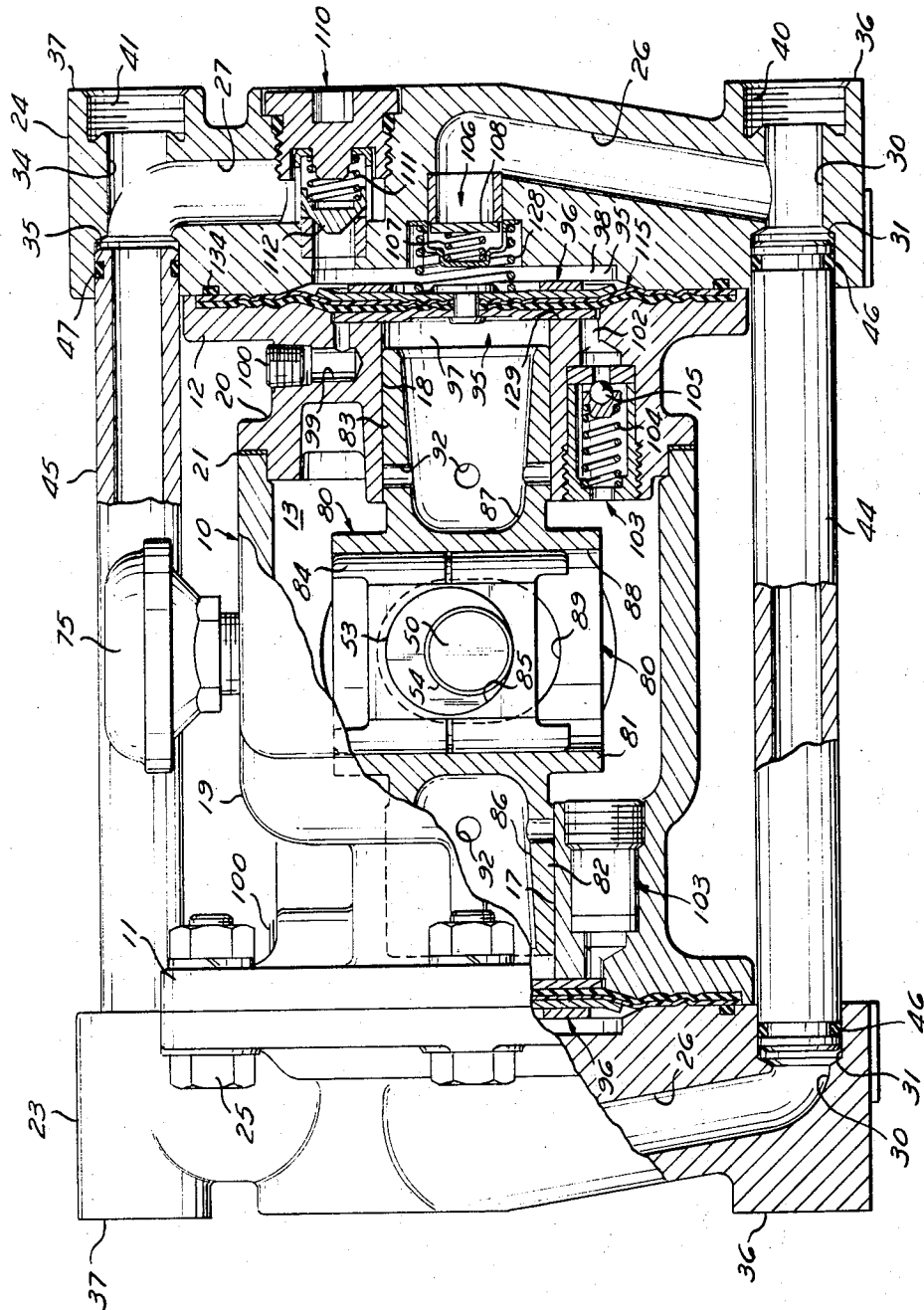
R. C. ACKER ET AL

3,354,831

PISTON DIAPHRAGM PUMP

Filed Nov. 4, 1966

3 Sheets-Sheet 1



INVENTOR.

RICHARD C. ACKER

BY

BY
MCNENNY, FARRINGTON, PEARNE, & GORDON

ATTORNEYS

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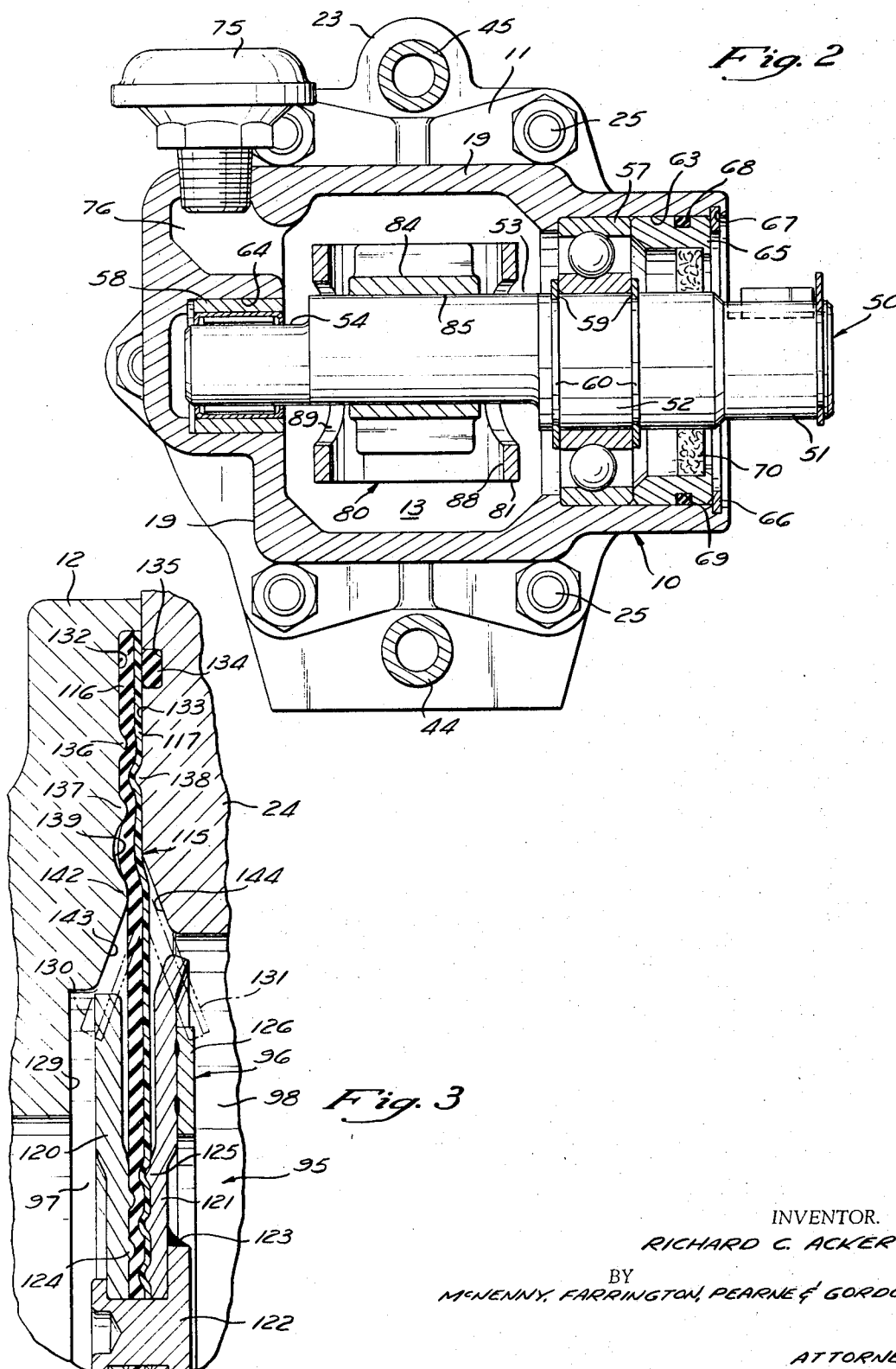
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INVENTOR.

RICHARD C. ACKER

BY

McNENNY, FARRINGTON, PEARNE & GORDON

ATTORNEYS

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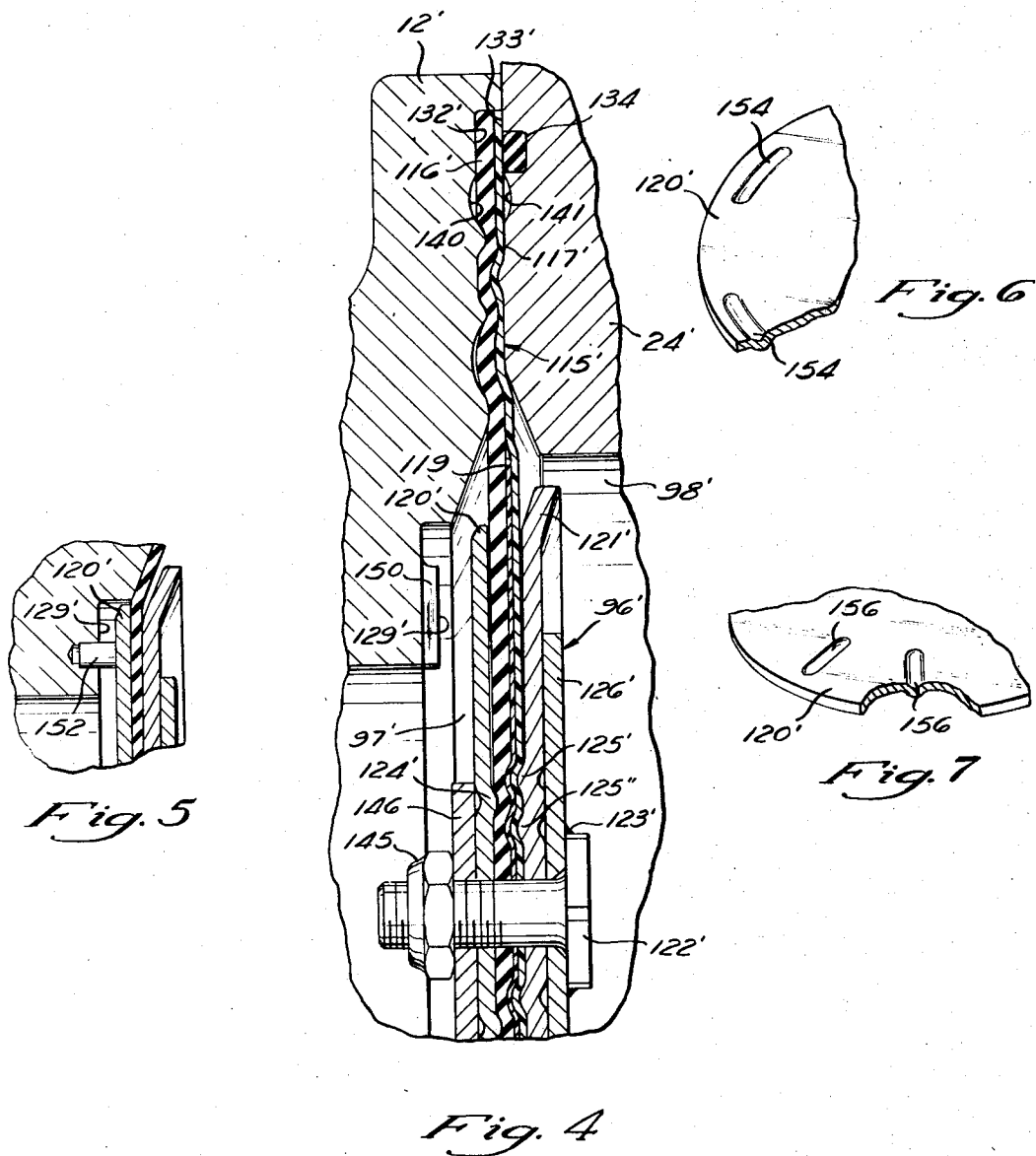
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3 Sheets-Sheet 3



INVENTORS
RICHARD C. ACKER,
& EUGENE BAHNIUK
BY
MCNENNY, FARRINGTON, PEARNE & GORDON

ATTORNEYS

1

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PISTON DIAPHRAGM PUMP

Richard C. Acker, Chagrin Falls, and Eugene Bahniuk,
Gates Mills, Ohio, assignors to The Weatherhead Com-
pany, Cleveland, Ohio, a corporation of Ohio
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12 Claims. (Cl. 103—44)

ABSTRACT OF THE DISCLOSURE

A diaphragm pump in which a diaphragm is moved by a working fluid on one side to vary the volume on the other side of the diaphragm to force the fluid being pumped in and out through inlet and outlet check valves. The working fluid is forced against the diaphragm by a cup-shaped piston acting in a cylinder and the chamber containing the diaphragm is provided with cylindrical recesses which cooperate with backing plates clamped on each side of the diaphragm to positively limit the axial movement of the diaphragm. The diaphragm is formed of a layer of resilient rubber material on the working fluid side and a layer of chemically resistant material on the pumping chamber side. In the central portion between the two plates, a layer of stiff plastic material is placed between the two diaphragm layers to control the flexing of the diaphragm. A spring is located within the pumping chamber to bias the diaphragm to a bottoming position where it rests on projections so that the working fluid acts on the full area of the diaphragm at all times. The diaphragm is mounted so that the central portion is stretched over an annular projection to prestress the diaphragm so that it is radially stressed at all times in its range of movement.

This is a continuation-in-part of the co-pending application of Richard C. Acker, Ser. No. 520,464, filed Jan. 13, 1966, now abandoned. This invention relates generally to pumps and more particularly to positive displacement pumps particularly adapted to transfer corrosive fluids.

When conventional positive displacement pumps are used with corrosive fluids, numerous problems are encountered. For example, it is necessary to use corrosion resistant materials for those parts in contact with the fluid, and such materials having sufficient strength are quite expensive. It is also necessary to prevent leakage of the corrosive material and contamination of the pump lubricant. Further, many corrosive fluids have a low degree of lubricity which tends to cause a high rate of wear between the moving parts of the pump.

One arrangement for overcoming these problems is to isolate the corrosive fluid from the moving parts by the use of a diaphragm and to oscillate the diaphragm by means of a piston acting on a non-corrosive actuating fluid such as oil in the space between the piston and the diaphragm.

One important application for pumps of this type is in a central air conditioning system operating on an absorption cycle and employing for its refrigerant a corrosive liquid such as an ammonia water solution. When air conditioning systems of this type are installed in homes and offices, the pump must meet a number of critical requirements and conditions. Because the pump is usually installed very close to inhabited areas, it is extremely important that the pump have a high degree of reliability against leakage of the solution which would result in the release of ammonia gas. In addition, the pump must be able to deliver a high volume and operate at a relatively low noise and vibration level. Also, the requirements of such refrigeration systems and the physical arrangement of the equipment often requires that the pump cannot be

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located in the optimum position with respect to the rest of the system so that it may have to operate at a relatively low inlet pressure. Another important problem is presented with the use of an ammonia water solution because sudden changes in the pressure of the fluid tend to cause the ammonia gas to vaporize and form bubbles within the liquid. This occurrence tends to result in hammering and noise when the liquid is placed under pressure.

In accordance with the preferred embodiment of this invention, the above and other problems have been solved or minimized by providing a pump having a pair of opposed cylinders within which slides a single double-ended piston oscillated by a scotch yoke drive to minimize acceleration and to reduce noise and vibration. Each cylinder is closed off at the outer end by means of a flexible diaphragm and a head having inlet and outlet valves therein. The pistons are substantially hollow so as to allow a large fluid space within the piston and cylinder for actuation of the diaphragm. The hollow pistons are provided with bleed openings to insure positive filling of the cylinders with the working fluid or oil present within the housing and to allow escape of any entrapped air within the oil. The maximum pressure of the oil acting on the diaphragm is controlled by means of a relief valve adapted to vent the working fluid from the diaphragm if the outlet pressure of the ammonia water solution rises above a predetermined level.

For long life, the diaphragm extends over a rounded annular projection which prestresses the diaphragm to prevent any flexing or folding as the diaphragm oscillates. To avoid any corrosive action by the ammonia water solution, the diaphragm is made of at least two layers, the one next to the corrosive fluid being of an inert and chemically resistant material such as polytetrafluoroethylene and the one next to the oil being of rubberized fabric to give the diaphragm tensile strength and assure a long flex life. The flex life of the diaphragm can be further increased by the addition of a layer of a stiff yet relatively flexible material such as nylon between the chemically resistant layer and the rubberized fabric to prevent extrusion of portions of the relatively soft chemically resistant layer over an extended period of operation.

The chamber within the head and the diaphragm support plate are arranged so as to insure a minimum clearance volume, and a positive spring return is provided for the diaphragm to insure positive filling of the diaphragm chamber even under extremely low inlet pressures. By the combination of the positive diaphragm return, the low clearance volume and the harmonic oscillation provided by the scotch yoke drive, any tendency of the ammonia to vaporize and produce hammer and vibration is greatly reduced. Furthermore, the start-up noise had been reduced by providing means to assure that the areas on opposite sides of the diaphragm assembly exposed to the oil and to the ammonia water solution are substantially the same so as to minimize any tendency for pressure peaks to occur in the oil before the initial movement of the diaphragm assembly during start-up. Also, the use of a single piston member with a scotch yoke drive not only allows the pump to be quite compact in size without sacrificing pump capacity but also provides the maximum simplicity necessary for low cost of manufacture and long operating life with a minimum of maintenance.

Additional features and advantages of the pump of the present invention will readily become apparent upon an examination of the drawings and the following detailed description of the preferred embodiment of the invention.

In the drawings:

FIGURE 1 is a partial longitudinal cross-sectional view of a pump constructed in accordance with the present invention;

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FIGURE 2 is a cross-sectional view taken along the axis of the drive shaft;

FIGURE 3 is a fragmentary view showing the clamping arrangement used to mount the diaphragm;

FIGURE 4 shows a modification of the diaphragm assembly, its clamping arrangement and the diaphragm cavity; and

FIGURES 5 through 7 each show different alternative means for spacing the support plate of the diaphragm assembly from the housing.

Referring to the drawings in greater detail, the pump comprises a housing 10 having a pair of end portions 11 and 12 and defining a fluid cavity 13. Extending outwardly from the fluid cavity 13 through the end portions 11 and 12 are a pair of cylinder bores 17 and 18 respectively.

In order to facilitate the assembly of the pump, the housing 10 is divided into a body section 19 and a cylinder section 20 secured together by a plurality of bolts (not shown) and sealed by a gasket 21.

A pair of head members 23 and 24 are secured to the end portions 11 and 12 respectively of the housing 10 by a plurality of bolts 25. Each head member is provided with an inlet passage 26 and an outlet passage 27. Each inlet passage is connected to the radial inner face of its associated head member by an axially extending counterbore 30 having an enlarged portion 31. Each outlet passage 27 is also connected to the radial inner face of its associated head member by a counterbore 34 having an enlarged portion 35. The head members 23 and 24 are substantially identical, the only difference being that the counterbores 30 and 34 on the head member 24 are drilled all the way through the bosses 36 and 37 and tapped to provide the pump with an inlet opening 40 and an outlet opening 41.

The inlet passages 26 in the head members 23 and 24 are interconnected by a transfer tube 44. The ends of the transfer tube 44 are disposed within the enlarged portions 31 of the counterbores 30 and sealed therein by O-ring seals 46. A similar transfer tube 45 disposed within the counterbores 34 and sealed therein by O-rings 47 interconnects the outlet passages 27 of each head member.

A drive shaft 50 extends through the fluid cavity 13 perpendicular to the axis of the cylinder bores 17 and 18. On one end of the drive shaft 50 is formed a drive portion 51 which extends beyond the housing 10 (see FIGURE 2) and is adapted to be connected to an electric motor or other suitable power source (not shown). The drive shaft is also provided with a first bearing portion 52, a crank portion 53 eccentric to the first bearing portion 52, and a second bearing portion 54 concentric with but of a smaller diameter than the first bearing portion 52.

The drive shaft 50 is rotatably mounted within the body section 19 of the housing 10 by a ball bearing assembly 57 disposed about the first bearing portion 52 and a needle bearing assembly 58 disposed about the second bearing portion 54. The ball bearing assembly 57 is slidably received within a bore 63 formed in the body section 19 and the needle bearing assembly 58 is press fitted within a counterbore 64 formed in the body section 19 on the opposite side of the fluid cavity 13. The ball bearing assembly 57 is retained on the shaft against axial movement by a pair of split realigning rings 59 disposed within a pair of grooves 60 formed on the outer surface of the shaft 50. This permits removal of the drive shaft 50 and ball bearing assembly 57 as a unit and gives free access to the parts located in the fluid cavity 13.

The drive shaft 50 is secured within the body section 19 by an annular spacer 65 which is disposed within the bore 63 in abutting engagement with the ball bearing assembly 57. A split retainer ring 66 is disposed in a groove 67 in the outer end of the bore 63 and retains both the spacer 65 and the ball bearing assembly 57 within the bore 63. The bore 63 is sealed by an O-ring 68 disposed in a recess 69 about the outer periphery of the spacer and by a packing ring or shaft seal 70 disposed between

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the inner periphery of the spacer 65 and the first bearing portion 52.

In order to ventilate the fluid cavity 13 and allow replenishment of the hydraulic fluid, a vent cap 75 is attached to the body section 19. The vent cap 75 is connected to the fluid cavity 13 through a passage 76 shown in FIGURE 2.

An elongated piston block 80 is centrally disposed within the fluid cavity 13. The piston block 80 includes a central portion 81 and a pair of cup-shaped piston portions 82 and 83 formed on its opposite ends. The piston portions 82 and 83 are received within the cylinder bores 17 and 18 in the housing 10.

A scotch yoke drive arrangement is used to impart a harmonic motion to the piston portions 82 and 83 as they reciprocate in the cylinder bores 17 and 18. The scotch yoke drive includes a bearing block 84 having a bore 85 in which the crank portion 53 of the drive shaft 50 is rotatably journaled.

The bearing block 84 is slidably disposed within a vertical bearing block slot 88 formed in the central portion 81 of the piston block 80. In order to allow the eccentric crank portion 53 of the drive shaft 50 to rotate relative to the vertically fixed piston block 80, the drive shaft extends through an enlarged opening 89 formed through the central portion 81 of the piston block 80 on opposite sides of the bearing block slot 88.

As the drive shaft 50 rotates, the piston block 80 is horizontally reciprocated by the bearing block 84. Since the bearing block 84 is limited to a vertical sliding motion relative to the piston block 80 by the bearing block slot 88, the eccentric motion of the crank portion 53 imparts a horizontal motion to the piston block 80.

The cup-shaped piston portions 82 and 83 are formed with recesses 86 and 87 adjacent the central portion 81 to minimize the reciprocating mass and insure a maximum volume of fluid within the working chamber. Adjacent the rear of each of the piston portions 82 and 83 is formed a plurality of radial ports 92 extending from the exterior into the recesses 86 and 87. These ports are uncovered and establish communication between the fluid cavity 13 and the recesses of the piston portions as the associated piston portion approaches the innermost extent of its intake stroke. In FIGURE 1, the piston block 80 is shown in a mid-point position and both sets of ports 92 are therefore closed. The purpose of these ports is to allow any entrapped air to escape from within the piston portions and to allow fluid from the fluid cavity 13 to flow into the piston portions to make up for any fluid lost by leakage.

Since both sides of the pump are identical in structure and mode of operation, only the right side as seen in FIGURE 1 will be described in further detail. The inner radial face of the head member 24 and the end portion 12 of the cylinder section 20 cooperate to form a diaphragm cavity 95. The diaphragm cavity 95 is divided by a diaphragm assembly 96 into a working fluid chamber 97 to the left of the diaphragm assembly 96 and a pumping fluid chamber 98 to the right of the diaphragm assembly 96.

The working fluid chamber 97 opens into the cylinder bore 18. At the top of the working fluid chamber 97 is an external filling port 99 closed by a plug 100. A relief check valve assembly 103 is mounted in the cylinder section 20 and connected to the bottom of the working fluid chamber 97 through a passage 102. Should a pressure build-up occur in the working fluid chamber 97 a ball type valve 105 in the relief valve assembly 103 is forced open against the load of spring 104 and the fluid from the working fluid chamber is bled back into the fluid cavity 13. The working fluid chamber 98 is connected to the inlet passage 26 by a pressure responsive poppet type inlet valve assembly 106 and to the outlet passage 27 by a pressure responsive poppet type discharge valve assembly 110.

In order to obtain a diaphragm that is both resilient and impervious to attack by the corrosive fluid being

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pumped, the diaphragm assembly 96 includes a laminated diaphragm 115. Referring to FIGURE 3, the side of the diaphragm 115 which is exposed to the non-corrosive working fluid comprises a layer of a resilient material 116 such as a rubber or neoprene impregnated fabric while the side which is exposed to the corrosive fluid being pumped comprises a layer of a highly chemically resistant material 117 such as polytetrafluoroethylene.

To support the central portion of the diaphragm 115, the diaphragm is sandwiched between a support plate 120 on its left side and a back up plate 121 on its right side as shown in FIGURE 3. The support plate 120 and the back up plate 121 are secured together by a rivet 122 extending through the diaphragm 115. To prevent leakage around the rivet, a seal is formed between the rivet 122 and the back up plate 121 as by welding the head of the rivet to the back up plate as shown at 123 or by any other suitable sealing means.

To minimize any tendency of the diaphragm 115 to tear around the rivet 122 and to aid in sealing between the support plate 120 and the back up plate 121, a series of cooperating annular ribs 124 and 125 are provided on the support plate and the back up plate respectively. Both the support plate 120 and the back up plate 121 are axially offset slightly at a point radially outwardly of the rib 125 to provide clearance on each side of the diaphragm 115. The clearance prevents binding of the diaphragm by the plates 120 and 121 thereby assuring that a greater radial extent of the diaphragm will be in tension than if the diaphragm were clamped between the plates 120 and 121 all the way to their outer periphery. Thus, the flexing action of the diaphragm is distributed over a greater area and the life of the diaphragm is lengthened.

A return spring 128 is provided between the back up plate 121 and the inner surface of the head member 24. The return spring 128 biases the diaphragm assembly 96 toward the piston portion 83 and into engagement with the stop surface 129 on the cylinder portion 20. Thus, the return spring 128 aids the piston portion 83 in moving the diaphragm assembly to the left in the diaphragm cavity 95 during the intake stroke to maximize the volume of the pumping chamber 98 and to assure a partial vacuum in the pumping chamber. By using the return spring 128, it is possible to obtain the maximum possible pressure differential across the inlet valve assembly 106 with a given inlet head. This is important when the pump must be mounted in a position relative to the remainder of the system which tends to reduce the inlet head to the pump. The return spring 128 is retained in a centered position on the back up plate 121 by a washer 126 secured to the back up plate.

Referring to FIGURE 3, the diaphragm is shown at its neutral or mid-point of oscillation while the phantom lines 130 and 131 illustrate the two extreme positions of oscillation. The diaphragm 115 is mounted within the diaphragm cavity 95 by having its outer periphery clamped between a clamping face 132 on the cylinder section 20 and a clamping face 133 on the head member 24. An O-ring 134 is disposed in a groove 135 in the clamping face 133 to form a seal between the outer layer of chemically resistant material 117 on the diaphragm 115 and the head member. To assure a seal and a positive grip between the clamping faces 132 and 133, a set of cooperating annular ribs 136, 137 and 138 are formed on the clamping faces 132 and 133 respectively.

A recess 139 is provided immediately adjacent the rib 137. The recess 139 receives any material extruded from between the clamping faces 132 and 133 when the outer periphery of the diaphragm 115 is clamped therebetween and serves as a relief to avoid any pressure on the diaphragm at this point.

A rounded annular protuberance 142 is formed on the end face of the end portion 12 immediately adjacent the recess 139. The rounded protuberance 142 extends axially beyond the clamping face 132 and terminates in an axially and radially inwardly tapering face 143. At 144

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the radial end face of the head member 24 tapers radially and axially inwardly of the head member from a point approximately opposite the mid-point of the recess 139 to a point opposite the tapered face 143 and below the rounded protuberance 142. Because of the tapered face 144, the diaphragm 115 is not clamped between the rounded protuberance 142 and the head member 24 but is offset with respect to the clamped portion. Thus, at the mid-point of oscillation or in the absence of the return spring 128, the remaining or unclamped portion of the diaphragm which divides the diaphragm cavity 95 is axially offset with respect to the portion clamped between the faces 132 and 133. This offsetting of the two portions of the diaphragm subjects the unclamped portion to a small initial stress.

By prestressing the unclamped portion of the diaphragm 115, the unclamped portion is not subjected to a compressive stress when the diaphragm passes through its neutral mid-point as it oscillates in the diaphragm cavity 95. Since the compressive stresses in the unclamped portion are minimized, the tendency for the diaphragm to develop folds in the unclamped forward portion along which the diaphragm may tear and fail is minimized.

Another important advantage of the rounded protuberance 142 is that it allows the stresses at the outer periphery of the diaphragm 115 to be distributed over a relatively large area with a rolling motion as the diaphragm oscillates. This prevents the stresses at the outer periphery of the unclamped portion from being concentrated along an annular line separating the clamped from the unclamped portions of the diaphragm. Since the stresses are not concentrated in an annular line, the tendency for the diaphragm to tear and fail along such a line adjacent the clamping faces is also minimized.

Operation

The fluid cavity 13 is filled through the opening for the vent cap 75 with a non-corrosive working fluid such as an oil having sufficient lubricity to lubricate the moving parts of the pump. The working fluid chambers 97 are filled by removing the plug 100 and introducing the working fluid through the filling port 99 as the drive shaft 50 is slowly rotated to move the piston portions 82 and 83 back and forth in the cylinder bores 17 and 18.

The corrosive fluid to be pumped enters the pump through the inlet port 40 and flows through the counter-bore 30 into the inlet passage 26 in the head member 24 and through the transfer tube 44 into the counter-bore 30 and inlet passage 26 in the head member 23.

As the drive shaft 50 rotates, the rotary motion of the eccentric crank portion 53 is translated into a horizontal reciprocation of the piston block 80 by the bearing block 84 sliding vertically in the bearing block slot 88. On the intake stroke, the piston portion 83 moves to the left in the cylinder bore 18 exerting a partial vacuum on the fluid in the working fluid chamber 97. This in conjunction with the action of the return spring 128 moves the diaphragm assembly 96 to the left in the diaphragm cavity 95 creating a partial vacuum in the pumping chamber 98.

The partial vacuum in the pumping chamber 98 creates a pressure differential across the inlet valve assembly 106. When the pressure differential is greater than the force exerted by the spring 107, the poppet inlet valve 108 is forced open by the pressure of the fluid in the inlet passage 26 and the fluid flows into and fills the pumping chamber.

On the discharge stroke, the piston portion 83 moves to the right in the cylinder bore 18 and the fluid in the working fluid chamber 97 forces the diaphragm assembly 96 to the right in the diaphragm cavity 95. The resulting increase in pressure on the fluid in the pumping chamber 98 closes the inlet valve 108 and creates a pressure differential across the discharge valve assembly 110. When the pressure differential is greater than the force exerted by the spring 111, the poppet valve 112 opens

and the fluid is discharged into the outlet passage 27 and out of the pump through the outlet port 41.

During the operation of the pump, the ports 92 are uncovered each time the piston portion 83 nears the innermost extent of the intake stroke. This allows any entrapped air to escape from the interior of the piston portion 83 and for fluid from the fluid cavity 13 to flow into the working fluid chamber 97 to replace the fluid lost by leakage.

Should an excessive pressure build-up occur in the working fluid chamber 97 during a discharge stroke of the piston portion 83, the ball check valve 105 is forced outwardly against the spring 104. This allows the excess pressure in the working fluid chamber 97 to bleed back into the fluid cavity 13 through the passage 102 and the relief valve assembly 103.

FIGURE 4 illustrates a modified embodiment of the diaphragm assembly and its clamping arrangement. In the embodiment of FIGURE 4, the end portion 12', head member 24' and diaphragm assembly 96' are, except as described hereinafter, generally similar to those illustrated in the embodiment of FIGURE 3 with the diaphragm assembly 96' including a layer of resilient material 116' and a layer of chemically resistant material 117' as in the embodiment of FIGURE 3.

Under certain conditions, when the chemically resistant layer 117' of the diaphragm 115' is of a relatively soft material there may be a tendency for the material to be extruded into the clearance space between the outer periphery of the back-up plate 121' and the wall of the pumping chamber 98' by the action of the layer 116'. After an extended period of operation this extruded portion may tear and the diaphragm fail.

The modified diaphragm construction illustrated in FIGURE 4 minimizes the extrusion of the layer 117' and substantially increases the operating life of the diaphragm. In order to prevent extrusion of the layer 117', a stiffer reinforcing disc 119 of a deformation resistant yet relatively flexible material such as nylon is interposed between the center portions of the layers 116' and 117'. This disc provides additional support for the layer 117', and reduces the tendency of the backing layer 116' to deform and force the layer 117' into the clearance space when the diaphragm assembly 96' is moved to the right under the action of the working fluid. The diameter of the disc 119 is substantially at least as great as that of the pumping chamber 98'. Preferably, however, the diameter should be slightly greater than that of the pumping chamber 98' in order to assure adequate support of the layer 117'.

Also illustrated in the embodiment of FIGURE 4 is a modified clamping arrangement for the diaphragm assembly 96'. The modified clamping arrangement includes a pair of annular recesses 140 and 141 in the housing end portion 12' and the head member 24' respectively. These recesses 140 and 141 receive any material displaced when the outer periphery of the diaphragm 115' is clamped between the clamping faces 132' and 133' to relieve any uneven forces which may be exerted upon the end portion 12' and the head member 24' by the deformation of the outer peripheral portion of the diaphragm 115'.

The support apparatus for the central portion of the diaphragm 115' is also slightly modified in the embodiment illustrated in FIGURE 4. In this embodiment the support plate 120' and the back-up plate 121' are clamped against the diaphragm 115' by a bolt 122' and a cooperating nut 145 which bears against a washer 146 on the outer surface of the support plate 120'. The head of the bolt 122' is sealingly secured to the washer 126' as by welding or brazing at 123'.

In this embodiment the support plate 120' is provided with a single annular rib 124' and the back-up plate 121' is provided with a pair of radially spaced annular ribs 125' and 125''. Also in this embodiment the support plate 120' and the back-up plate 121' are not axially offset to

provide the clearance along the diaphragm 115' as in the embodiment of FIGURE 3. In the embodiment of FIGURE 4, an adequate clearance is provided between the diaphragm 115' and the plate 120' and 121' by utilizing the inherent resistance to deformation of the diaphragm 115' by the ribs 124', 125' and 125'' when the nut 146 is tightened to keep the plates 120' and 121' spaced apart a distance greater than the thickness of the diaphragm 115'.

As the nut 146 is tightened and the plate 120' and 121' move together the ribs 124', 125' and 125'' deform the diaphragm 115'. Since these ribs are blunt, the diaphragm 115' will not be deformed sufficiently to allow the entire radial extent of the plates 120' and 121' to clamp the diaphragm 115'. Thus, an adequate clearance is provided between the diaphragm 115' and the plates 120' and 121' in the area extending radially outwardly from the rib 125'. The diaphragm material will also be deformed radially inwardly by the ribs 124' and 125'' and will tend to fill the space between the rib 124', 125' and the shank of the bolt 122'. This tends to limit further deformation of the diaphragm 115' and forms a seal around the shank of the bolt 122'.

Under certain operating conditions, notably after the pump has been at rest for a period of time, the pump of the embodiment shown in FIGURE 3 may produce an objectionable noise as it starts up. This noise is produced by the occurrence of high pressure peaks in the working fluid prior to the initial movement of the diaphragm assembly 96.

In the arrangement of FIGURE 3 after the pump has been at rest for a period of time with the fluid being pumped still under pressure, a stable condition is reached wherein the support plate 120 of the diaphragm assembly 96 is resting against the stop surface 129. This drift of the diaphragm assembly 96 to the left within the diaphragm cavity 95 from the centered or neutral position is produced by a number of factors including the action of the pressurized fluid being pumped and the spring 128 (not shown in FIGURE 3) upon the right hand side of the diaphragm assembly 96. These factors result in the exertion of enough force on the diaphragm assembly 96 to pressurize the working fluid within the working fluid chamber 97. After a period of time the working fluid is forced through the clearance between the piston portion 83 and the wall of the cylinder bore 18 into the fluid cavity 13 which is at atmospheric pressure because of the vent 75 and the diaphragm assembly 96 drifts to the left until it engages the stop surface 129.

In this stable condition the support plate 120 tends to form a seal with the stop surface 129 around the outer edge of the cylinder bore 18. When the pump is started up movement of the piston portion 83 to the right increases the pressure of the working fluid within the cylinder bore portion of the working fluid chamber 97 and because of the seal formed by the support plate 120 around the outer edge of the cylinder bore 18, this pressure acts upon the diaphragm assembly 96 over an area only equal to the cross-sectional area of the cylinder bore 18. Since the fluid being pumped in the pumping fluid chamber 98 acts on a much greater area on the diaphragm assembly 96 relatively high pressure peaks occur in the cylinder bore 18 before initial movement of the diaphragm assembly 96 to the right within the diaphragm cavity 95 can occur. The resulting hammering sound created by these high pressure peaks produces a disturbing noise level in the surrounding environment. If initial start up piston movement is to the left, a vacuum condition in chamber 95 results which causes high start up torque requirements, noise and release of entrapped air from the working fluid.

It was found that the start up noise could be reduced if the support plate 120 were not allowed to engage the stop surface 129 in such a manner as to form a seal with it or around the outer edge of the cylinder bore 18.

Several arrangements are shown in FIGURES 4 through 7 for overcoming this problem.

In the embodiment of FIGURE 4 stop surface 129' is provided with a plurality of radially extending grooves or channels 150 which interrupt the area of engagement between the stop surface and the support plate. The grooves 150 prevent a seal from tending to be formed and allow the pressure of the working fluid to be distributed over the entire left side of the diaphragm assembly 96' which has an area substantially equal to the area on the right side of the diaphragm assembly acted upon by the fluid being pumped.

FIGURE 5 schematically illustrates a different alternative arrangement wherein the support plate 120' of the diaphragm assembly 96' is spaced from the stop surface 129' by a plurality of pin-like members 152 secured in the housing and disposed circumferentially about the stop surface and extending into the space between the support plate and stop surface. Another and different alternative arrangement is shown in FIGURES 6 and 7 wherein a plurality of projections are formed on the support plate 120' for spacing a substantial portion of said support plate from said stop surface. In FIGURE 6 these projections are in the form of a plurality of circumferentially spaced annularly extending ribs 154. FIGURE 7 illustrated the projections as being circumferentially spaced radially extending ribs 156.

While the preferred embodiments of this invention have been shown and described in considerable detail, it is recognized that the invention is not limited to the specific forms shown and described and various modifications and rearrangements may be made without departing from the scope of the invention as defined in the following claims.

What is claimed is:

1. A pump comprising a housing member defining a fluid cavity and a cylinder bore, a piston in said cylinder bore, drive means to reciprocate said piston, a head member secured to said housing defining a diaphragm cavity at the outer end of said cylinder bore, a diaphragm separating said diaphragm cavity into working chamber opening to said cylinder bore and a pumping chamber, said diaphragm being of a laminated construction having a first layer of resilient elastomeric material and a second layer of a highly chemically resistant material exposed to the fluid in the pumping chamber, said diaphragm having a relatively stiff reinforcing disc disposed between said first and second layers, said disc having an outer diameter substantially at least as great as the diameter of said pumping chamber, mounting means securing the outer periphery of said diaphragm to one of said members including a pair of opposed clamping faces, one of said clamping faces having a rounded annular protuberance adjacent its inner periphery extending axially beyond said clamping face and the other of said clamping faces having a recessed surface adjacent its inner periphery opposite said protuberance, said mounting means being so constructed and arranged that when said diaphragm is clamped between said clamping faces said protuberance and said recessed surface are axially separated from one another by at least substantially the thickness of said diaphragm, said protuberance axially offsetting the unclamped from the clamped portions of said diaphragm and thereby prestressing the unclamped portion, inlet and outlet ports opening into said pumping chamber, and valve means in said inlet and outlet ports, whereby reciprocation of said piston acts upon fluid within said working chamber and imparts oscillation to said diaphragm to draw fluid into and force fluid out of said pumping chamber.

2. A pump as set forth in claim 1 wherein said reinforcing disc is of a nylon material.

3. A pump comprising a housing member defining a fluid cavity and a cylinder bore, a piston, a head member secured to said housing defining a diaphragm cavity at the outer end of said cylinder bore, a diaphragm separat-

ing said diaphragm cavity into a working chamber opening into said cylinder bore and a pumping chamber, mounting means securing the outer periphery of said diaphragm to one of said members including a pair of opposed annular clamping faces defining an annular clamping zone, one of said members having a rounded annular protuberance radially inward of said clamping zone extending axially beyond said clamping face and the other of said members having a recessed surface radially inward of said clamping zone opposite said protuberance, said mounting means being so constructed and arranged that when said diaphragm is clamped between said clamping faces at said clamping zone said protuberance and said recessed surface are axially separated from one another by at least the thickness of said diaphragm, said protuberance axially offsetting the unclamped from the clamped portions of said diaphragm and thereby prestressing the unclamped portion so that said diaphragm is radially stressed at all times, inlet and outlet ports opening into said pumping chamber, and valve means in said inlet and outlet ports, whereby reciprocation of said piston acts upon fluid within said working chamber and imparts oscillation to said diaphragm to draw fluid into and force fluid out of said pumping chamber.

4. A pump as set forth in claim 3 wherein the center section of said diaphragm is provided with a support plate on the working chamber side and a back-up plate on the pumping chamber side, and means interconnecting said support plate and said back-up plate to clamp said diaphragm therebetween.

5. A diaphragm mounting arrangement including a first member having a first annular clamping face, a second member having a second annular clamping face of substantially the same radially dimensions as said first clamping face, means securing said first and second members together with said first and second clamping faces being axially opposed to and facing one another to define an annular clamping zone, a diaphragm having a portion of its outer periphery clamped between said first and second clamping faces at said clamping zone, a rounded annular protuberance on said first member radially inward of said clamping zone projecting axially beyond said first clamping face toward said second clamping face, said second member having a recessed surface radially inward of said clamping zone and axially opposite said annular protuberance and spaced therefrom by a distance greater than the thickness of said diaphragm whereby the unclamped portion of said diaphragm is axially offset from said clamped portion and said unclamped portion is thereby prestressed at all times.

6. A device as set forth in claim 5 wherein an annular recess is provided in said first member radially between said clamping zone and said annular protuberance.

7. A pump comprising a housing member defining a fluid cavity and a cylinder bore, a piston in said cylinder bore, drive means to reciprocate said piston, a head member secured to said housing and defining a diaphragm cavity at the outer end of said cylinder bore, a diaphragm assembly separating said diaphragm cavity into a working chamber opening into said cylinder bore and a pumping chamber, whereby reciprocation of said piston acts upon fluid within said working chamber and imparts oscillation to said diaphragm assembly to draw fluid into and force fluid out of said pumping chamber, mounting means securing the outer periphery of said diaphragm to one of said members including a pair of opposed clamping faces, the center section of said diaphragm being provided with a support plate on the working chamber side and a back-up plate on the pumping chamber side, means interconnecting said support plate and said back-up plate, said housing defining a stop surface adjacent the outer end of said cylinder bore, said stop surface and said support plate being so constructed and arranged as to engage one another and limit the inward travel of said diaphragm assembly toward said working chamber, and means

adapted to interrupt the area of engagement between said support plates and said stop means to prevent the support plate and stop surface from forming a continuous seal therebetween.

8. A pump set as set forth in claim 7 wherein said interrupting means comprises a channel in said stop surface communicating at one end with said cylinder bore through the wall thereof.

9. A pump as set forth in claim 7 wherein said interrupting means comprises spacer means spacing a substantial portion of said support plate from said stop surface.

10. A pump as set forth in claim 9 wherein said spacer means comprises a plurality of pin-like members extending into the space between said stop surface and said support plate.

11. A pump as set forth in claim 9 wherein said spacer means comprises a plurality of projections on said support plate extending toward said stop surface.

12. A piston-diaphragm pump comprising a housing defining a working fluid cavity and having a pair of end portions and a pair of cylinder bores extending from said end portions and opening into said fluid cavity, said housing being composed of a body section and a removable cylinder section, said cylinder section including one of said end portions and the adjacent cylinder bore, a pair of head members secured to said housing end portions and defining with each of said end portions a diaphragm cavity opening into each of said bores, a flexible diaphragm in each diaphragm cavity dividing the diaphragm cavity into a working fluid chamber and a pumping chamber, each diaphragm being clamped about its outer periphery between a pair of clamping faces formed on the adjacent surfaces of the head members and the end portions of said housing, each of said head members having an intake port and a discharge port communicating with the pumping chamber, a pressure responsive intake valve in each of said intake ports and a pressure responsive discharge valve in each of said discharge ports, transfer tube means extending between said head members having passageways interconnecting the intake and discharge ports of one head member with the respective intake and discharge ports of the other head member, an elongated piston block having cup shaped piston portions on opposite ends thereof and a bearing block slot through the center, the axis of said slot being perpendicular to the longitudinal axis of said piston portions, each of said cup shaped piston portions having a port formed therein extending from the exterior to the interior of said cup shaped piston portion and being so arranged as to be opened and establish communication between the working chamber and the fluid cavity as the piston portion reaches the inward extremity of the intake stroke and to be closed during the major portion of the working stroke, a bearing block slidably disposed within said

bearing block slot and having a crank receiving aperture extending therethrough on an axis perpendicular to the axis of said bearing block slot, bearing means disposed within said housing for rotatably supporting a shaft, a shaft mounted within said housing and having axially spaced journal portions received within said bearing means and an eccentric crank portion received within said crank aperture, said housing having a passageway extending from said working fluid chamber to said fluid cavity with a pressure relief valve therein adapted to open and relieve any excess pressure developing in said working fluid chamber and said piston chamber during the outward working stroke of said piston, a diaphragm biasing spring extending between said diaphragm and its associated head member and biasing the diaphragm inwardly toward its associated piston member, said diaphragm having a laminated construction with the major portion being a resilient elastomeric material and the pump fluid exposed surface being a layer of highly chemically resistant plastic material, a pair of diaphragm support plates secured to the opposite faces of said diaphragm and covering the central portion of said diaphragm, stop means immediately adjacent the inner portion of the working chamber in such a position as to engage one of said support plates and limit the inward travel of the diaphragm, a rounded axially extending annular protuberance on one of said members, about the outer periphery of said diaphragm cavity and immediately adjacent the diaphragm clamping face, said protuberance extending axially beyond adjacent portion of the clamping face of the member upon which it is formed, said protuberance engaging the diaphragm and offsetting the centerline of the unclamped from the clamped portion thereby subjecting the unclamped flexing portion of the diaphragm to a slight initial stress when the diaphragm is in its midpoint position.

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ROBERT M. WALKER, *Primary Examiner.*