

June 26, 1956

C. D. HOOVER

2,751,850

DIAPHRAGM STRUCTURE AND DEVICE EMBODYING IT

Filed April 25, 1949

4 Sheets-Sheet 1

Fig. 1.

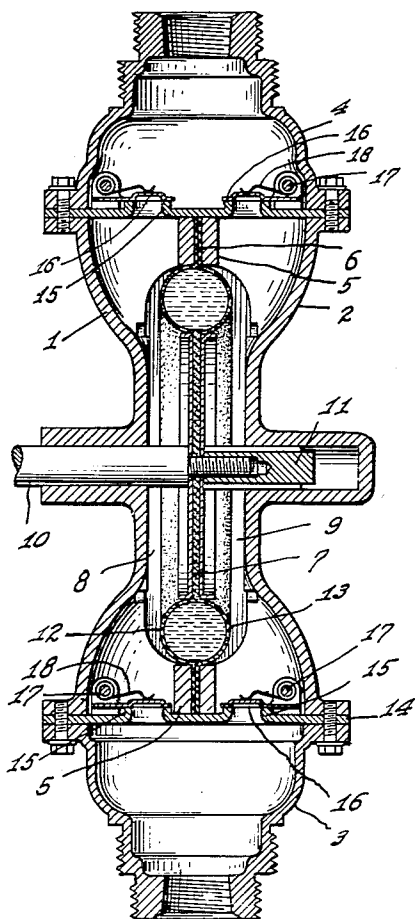


Fig. 2.

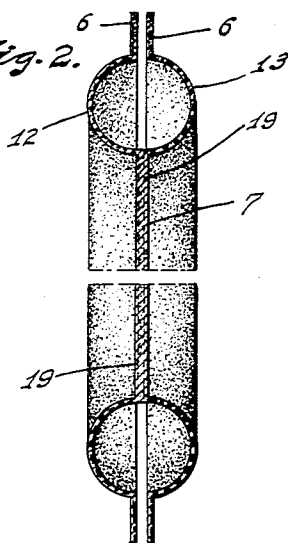


Fig. 3.

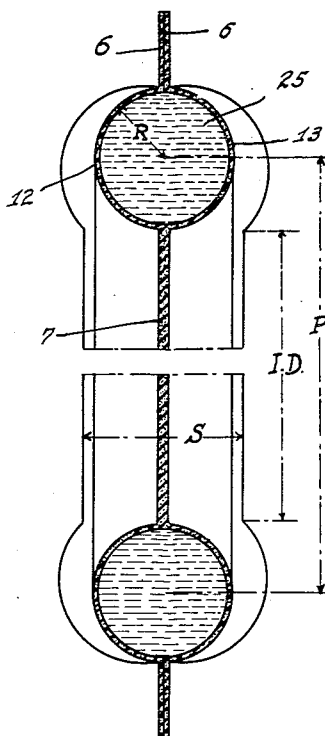


Fig. 4.

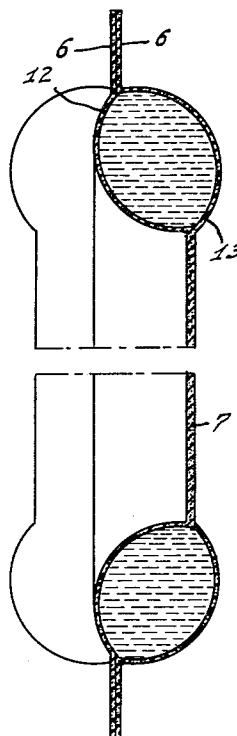


Fig. 13.

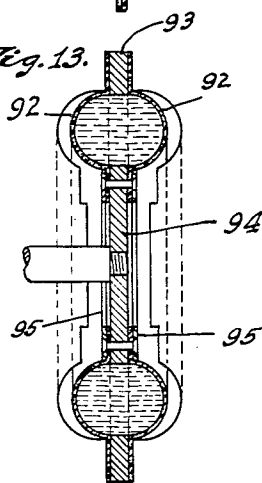
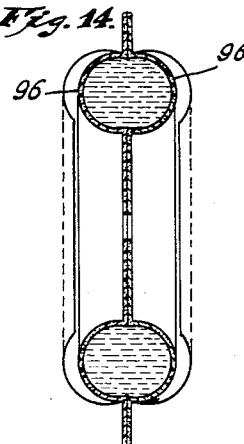


Fig. 14.



INVENTOR.
CHARLES D. HOOVER,

BY *Schley, Darr & Jenkins*

ATTORNEYS.

June 26, 1956

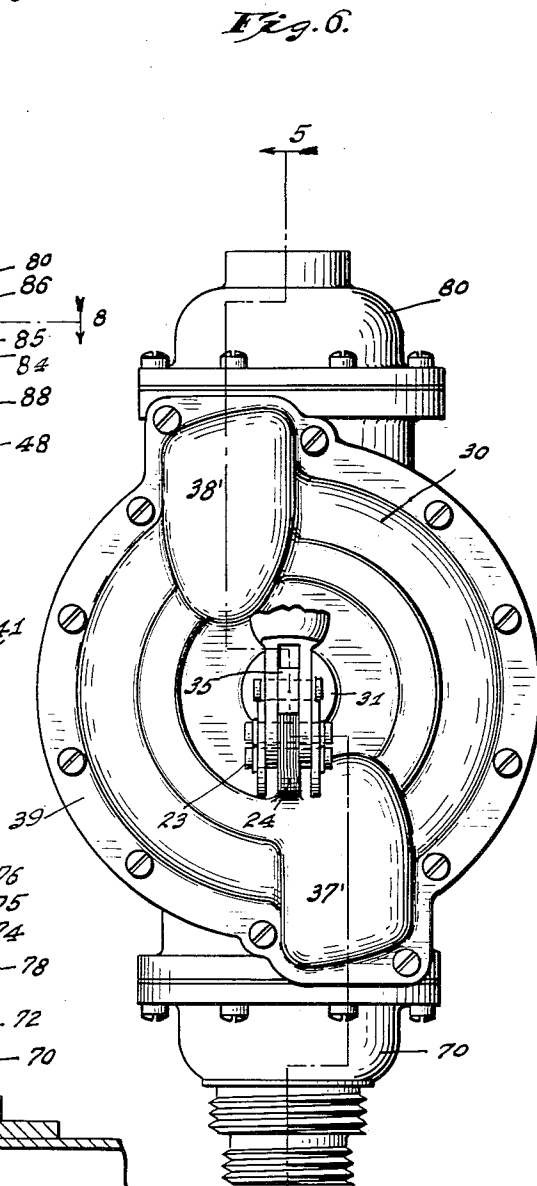
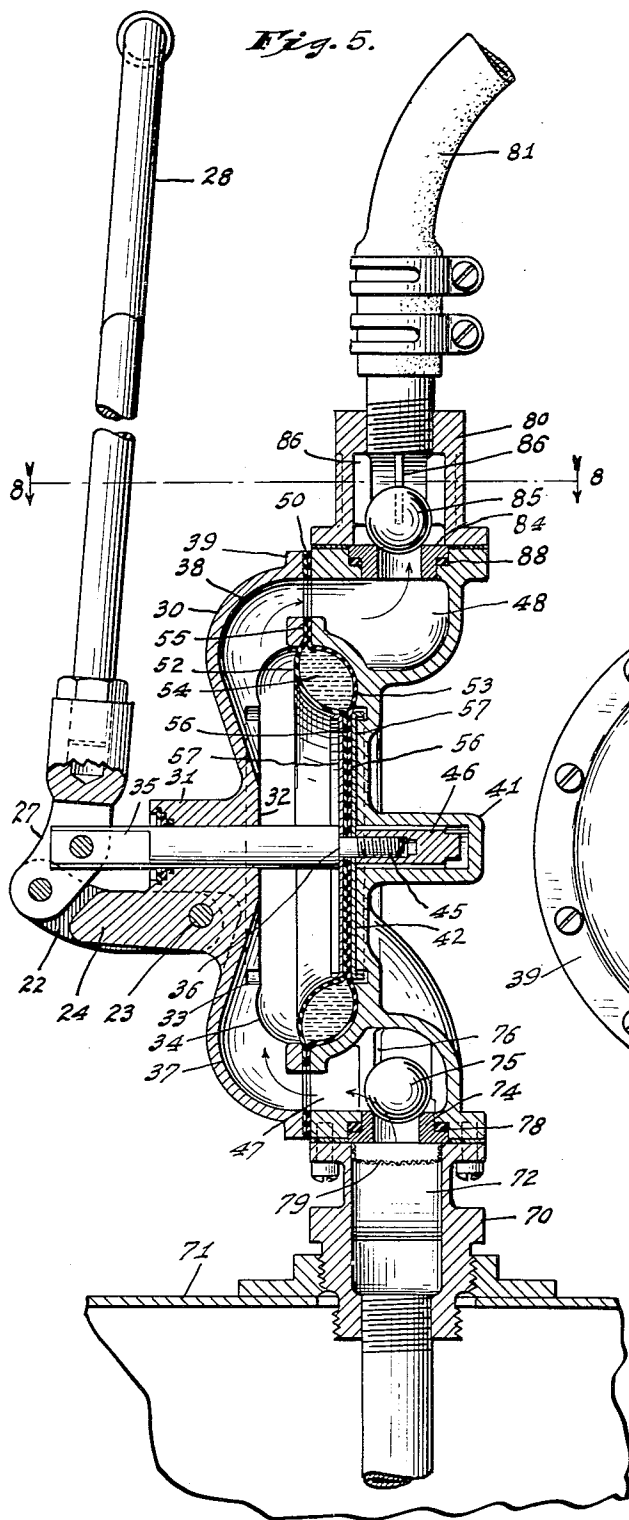
C. D. HOOVER

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DIAPHRAGM STRUCTURE AND DEVICE EMBODYING IT

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4 Sheets-Sheet 2



INVENTOR.
CHARLES D. HOOVER,

BY
Schley, Dashi & Jenkins
ATTORNEYS.

June 26, 1956

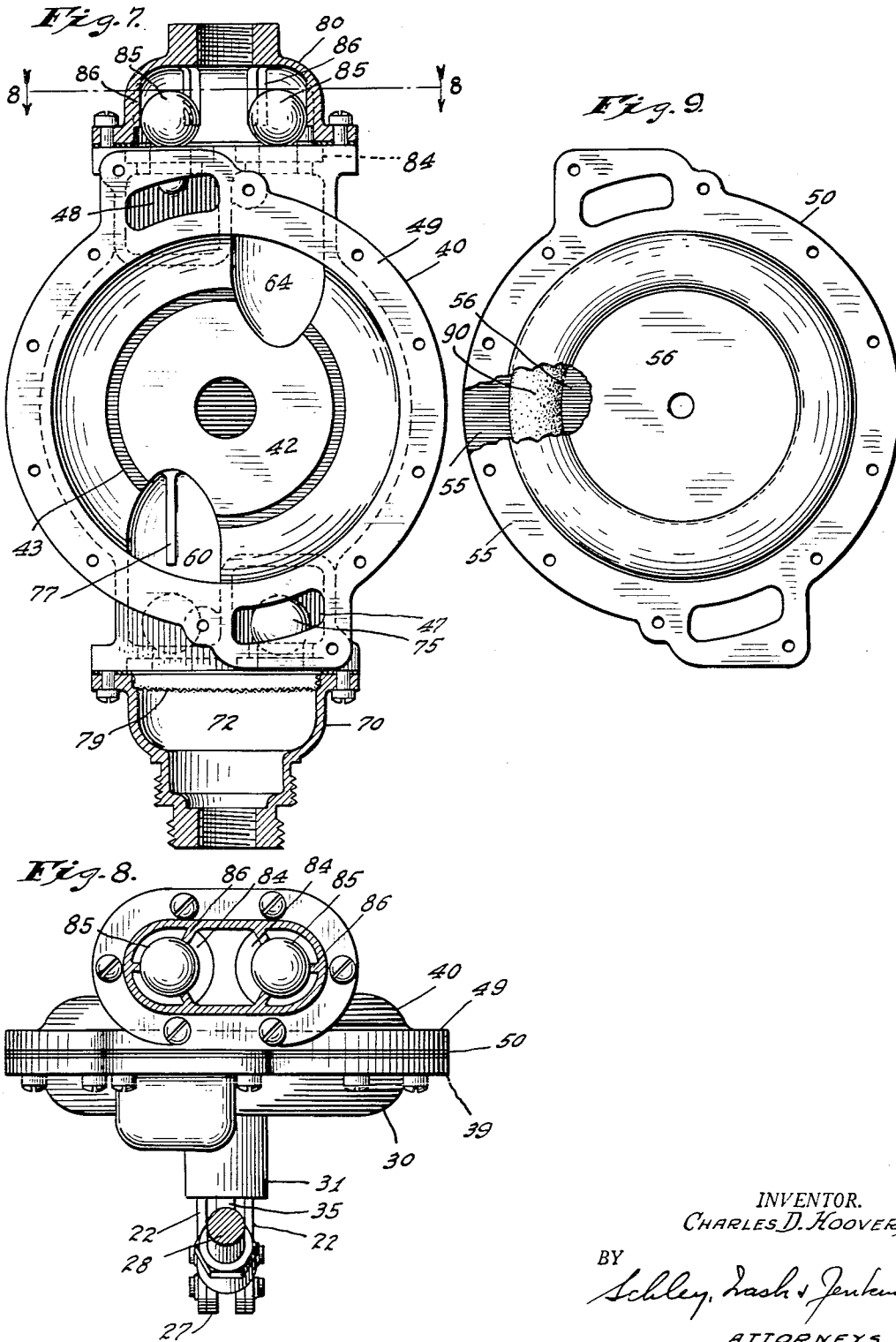
C. D. HOOVER

2,751,850

DIAPHRAGM STRUCTURE AND DEVICE EMBODYING IT

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4 Sheets-Sheet 3



INVENTOR.
CHARLES D. HOOVER,

BY
Schley, Dash & Jenkins
ATTORNEYS.

June 26, 1956

C. D. HOOVER

2,751,850

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Fig. 10.

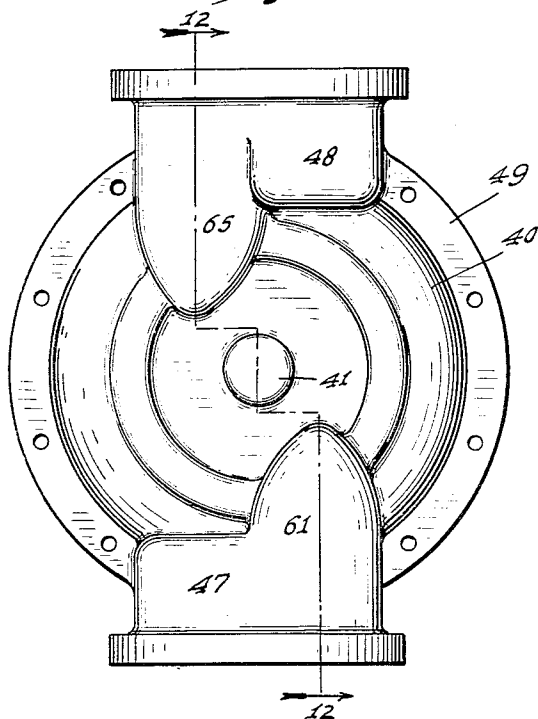


Fig. 12.

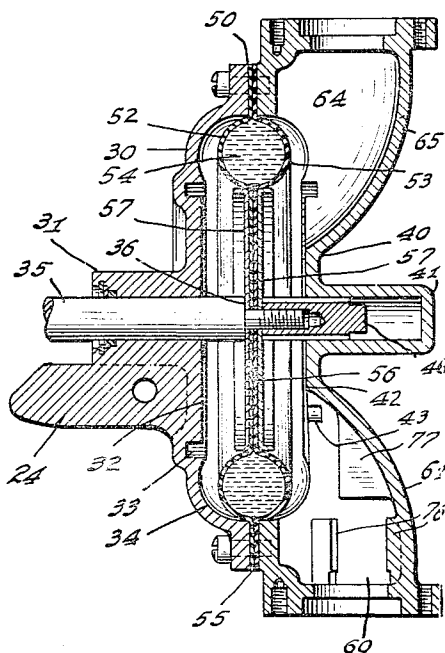
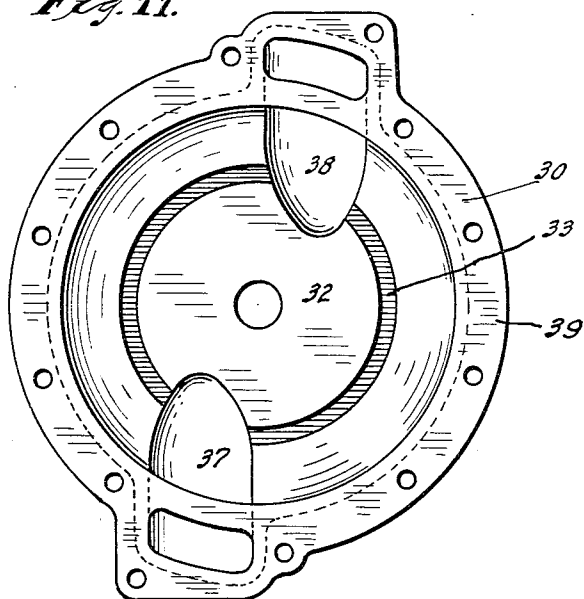


Fig. 11.



INVENTOR.
CHARLES D. HOOVER,
BY
Schley, Dashi & Jenkins
ATTORNEYS.

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DIAPHRAGM STRUCTURE AND DEVICE EMBODYING IT

Charles D. Hoover, Fort Wayne, Ind., assignor to Tokheim Corporation, a corporation of Indiana

Application April 25, 1949, Serial No. 89,448

6 Claims. (Cl. 103—150)

This invention relates to a diaphragm structure adapted to be subjected to varying or alternating forces, as in diaphragm devices such as fluid pumps, fluid meters, and fluid motors; and to devices embodying such diaphragm structure. More particularly, the invention involves a diaphragm having a pre-formed, generally toroidal, working annulus.

With the usual membrane diaphragm, for example in a diaphragm pump, the condition of the working annulus of the diaphragm membrane changes greatly during its stroke. At the ends of strokes, the annulus may be pulled straight in a frusto-conical form, while at intermediate points of the strokes it is quite loose and bulges rearward in alternate directions as the stroke directions change, so that stroke movements involve considerable lost motion which is ineffective to produce any pumping. Such ineffective lost motion is inherent and can be reduced only by more nearly approaching straightness of the membrane at the ends of the stroke, in which case the working pressures, acting perpendicular to the straight membrane, resolve themselves into a disproportionate and excessive increase in stress on the diaphragm.

It is the object of my invention to provide an improved, more efficient, and more sensitive diaphragm structure and device embodying it. It is my object to provide a diaphragm structure in which no such ineffective lost motion occurs. Another object of the invention is substantially to avoid the creation of extreme stress in the working annulus of the diaphragm, and thus to increase greatly the life and the practical applications of diaphragm mechanism. It is a further object of the invention to obtain a greater effective displacement ratio in a diaphragm device. Other objects of the invention will appear from the following specification.

In accordance with one aspect of the invention, a diaphragm is made having a generally toroidal working annulus, and suitable means are provided at the inner and outer peripheries of such annulus, for example inner and outer peripheral rims or an outer rim and an inner web, by which the inner and outer peripheries may be reciprocated axially with respect to each other to carry the working annulus through its working strokes. Desirably, the working annulus has outer walls which are pre-formed to a generally toroidal shape, each axial half of which is so formed that at least one point in the stroke, preferably the mid-point, its cross-section is semi-circular; and the toroidal cavity defined by such walls contains a deformable filling, for example, liquid. The walls of the working annulus are flexible, and desirably are substantially inelastic, although not necessarily so. I prefer to make the walls substantially non-stretchable under the force imposed by the medium upon which the diaphragm is to work. The filling of the toroidal cavity is desirably incompressible and readily deformable, and a preferred filling is a liquid which is inert toward the material of the diaphragm walls. Surprisingly, however, I find that the filling may be solid, for example of relatively soft, deformable rubber; and when a solid filling is used, it is desirably pre-formed as a ring to fit the pre-formed toroidal cavity of the diaphragm. For some applications, I contemplate a compressible filling for the diaphragm. The filling may also be under pressure; for

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example, the toroidal cavity may be filled with liquid under pressure, or substantially the effect of an incompressible filling may be obtained by filling the cavity with a gas under a pressure above that of the pressure of the medium upon which the diaphragm is to work.

In accordance with another aspect of my invention, a diaphragm structure of the character described is combined in a device having means to actuate the diaphragm through a stroke of limited length in relation to the cross-section diameter of the toroidal working annulus of the diaphragm. With a limited stroke length, the torus walls are maintained in deeply arcuate section throughout the stroke, which minimizes bending and tension stresses on the diaphragm walls and avoids disproportionate stress increases such as occur when a diaphragm is drawn toward flatness. Moreover, I find that by using a stroke of such limited length, the volume and wall-length of the toroidal annulus are maintained substantially constant, or kept to a change below any desired small proportion.

In accordance with another aspect of the invention, a diaphragm of the type described above is associated with a housing shaped to provide a minimum clearance space between the housing and the diaphragm at the end of its stroke, to obtain a high displacement ratio, and hence produce high lift of high vacuum.

My invention is especially applicable to a hand operated pump for liquids, and is described with respect thereto in the following specification.

The accompanying drawings illustrate my invention.

In such drawings, Fig. 1 is an axial section through a pump embodying my invention, showing a preferred form of valve structure but with that valve structure disposed in an arrangement less preferred than that shown in Figs. 5 to 8; Fig. 2 is an axial section through a preferred diaphragm structure in its as-molded condition, which has an integral central web and separate peripheral rims and contains fabric reinforcements in its walls; Fig. 3 is a diagrammatic section of a diaphragm embodying my invention, with the diaphragm shown in working condition and at the mid-point of its stroke; Fig. 4 is a view similar to Fig. 3, but showing the diaphragm in an extreme position at one end of its stroke; Fig. 5 is a vertical section of a hand-operated, double acting liquid pump embodying my invention and employing a two-piece diaphragm, showing the diaphragm at the rear end of its stroke, and taken on the line 5—5 of Fig. 6 so that it shows the inlet and outlet passageways to the displacement space at the front (to the left) of the diaphragm; Fig. 6 is a front elevation of the pump shown in Fig. 5; Fig. 7 is a view similar to Fig. 6 but with the front half of the pump casing and the diaphragm removed, and with the end fittings shown in section; Fig. 8 is a horizontal section of the pump shown in Figs. 5 to 7, taken on the line 8—8 of Fig. 8 (or of Fig. 5); Fig. 9 is a front elevation of a diaphragm structure such as that used in the pump of Figs. 5 to 8, with a portion broken away and showing the filling as a solid rubber ring instead of the liquid filling indicated in preceding views; Fig. 10 is a rear elevation of the rear half of the pump casing shown in Fig. 5; Fig. 11 is a rear elevation of the front casing half; Fig. 12 is a vertical section of the pump shown in Fig. 5, taken on the line 12—12 of Fig. 10, so that it shows the inlet and outlet passageways for the displacement space behind (to the right of) the diaphragm; Fig. 13 is a view similar to Fig. 3, showing a modified diaphragm structure in which two annular diaphragm shells are mounted against opposite faces of spacers; and Fig. 14 is a view similar to Fig. 3, showing in accentuated form a two-piece diaphragm in which the opposite walls of the working annulus have a cross section greater than a semi-circle.

The pump shown in Fig. 1 comprises a front casing 1,

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a rear casing 2 symmetric with the front casing, a bottom intake fitting 3, and a top discharge fitting 4. The casings 1 and 2 have continuous annular flanges 5, between which the outer peripheral rims 6 of the diaphragm are clamped, and the casings form a front displacement space 8 and a rear displacement space 9 on opposite sides of the diaphragm. The diaphragm has a central circular web 7 which is supported on opposite sides by suitable circular plates clamped together and adjacent a shoulder on the operating shaft 10 by means of the nut 11 screwed onto the reduced end of the shaft 10.

Between the central web and the peripheral rims 6 of the diaphragm, the working annulus of the diaphragm is shaped as a hollow torus having front and rear walls 12 and 13 each of which is pre-formed to substantially semi-circular cross section. The working annulus thus forms a substantially true torus and has a cavity of circular cross section. Such cavity is filled, desirably with an incompressible liquid, and it may be filled under a slight pressure, for example about one half pound per square inch.

The intake and discharge valves are of identical construction, and comprise a plate 14 clamped against each end of the casing assembly, between it and the respective end fittings 3 and 4. Each valve plate 14 is punched and flanged upwardly to form a pair of valve openings bounded by upstanding rims 15, on opposite sides of the assembled flanges 5, and the rims 15 are dressed to form planar valve seats. Flap valves 16 seating on the valve seats of the rims 15 are loosely pivoted by upstanding ears on eccentric pivots 17 mounted between lugs secured to the plate 14, and the valves are urged to closed position by pressure applied adjacent their centers by the down-turned ends of springs 18 coiled about the pivots 17. Conveniently, the valve openings are of generally oval cross-sectional shape, and the section of Fig. 1 may be considered as taken on their minor axes.

With the intake fitting 3 connected to a source of liquid, reciprocation of the operating shaft 10 through strokes in opposite directions produces a double-acting pumping effect. As the shaft 10 moves to the left, it carries the web of the diaphragm bodily to the left and rolls the working annulus on the conforming walls of the pump cavity. This increases the volume of the rear displacement space 9, to draw liquid into that space through the (lower right) valve between the intake fitting 3 and the rear displacement space 9. Simultaneously, the front displacement space is reduced in volume, to discharge liquid therein through the (upper left) valve between that displacement space 8 and the discharge fitting 4. A corresponding action occurs upon the opposite stroke of the shaft 10, to draw liquid into the displacement space 8 through its associated intake valve, and to discharge liquid from the displacement space 9 through its associated discharge valve.

The diaphragm is preferably molded in one piece, as shown in Fig. 2, with an integral central circular web 7, joined at its edge to the two semi-circular walls 12 and 13 of the toroidal working annular portion. In a preferred diaphragm construction, the body of the diaphragm contains a pair of fabric reinforcing sheets 19, indicated by dotted lines in Fig. 2. In preparing the diaphragm, the two reinforcing sheets are heavily impregnated with raw body material, and the impregnated sheets are assembled in a mold, and molded and cured therein. The mold preferably includes an insert conforming to the desired inner surface of the toroidal working annulus, supported by a thin peripheral web which lies between the rims 6 during the molding operation. The molding and curing step integrally joins the web portions of the raw sheets, pre-forms the working annulus to the desired toroidal shape, and forms the rims 6 separately so that the finished diaphragm may be stripped from the inner mold form.

The pre-formed molded diaphragms may be made of any of a number of materials which in cured state will

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be suitably flexible and desirably relatively inelastic. Suitable materials include various synthetic rubbers and rubber-like compositions, and flexible synthetic plastic materials. A highly satisfactory diaphragm is made from single braid cotton cloth impregnated with perbunan rubber.

The rims 6 of a diaphragm body molded to the shape shown in Fig. 2 may be sealed together over substantially their whole area, leaving a small unsealed opening, and the toroidal cavity is then filled through the small opening, as with a liquid 25 which may be under slight pressure, and the small opening is then sealed; which produces a unitary filled diaphragm which may be handled and installed in the pump as a unit. When so installed in the pump, the rims 6 are clamped in sealed engagement between the flanges 5 of the pump, and the clamping strengthens the seal and prevents any possibility of separation between those two rims 6.

The diagrammatic sectional views of Figs. 3 and 4 show the action of the diaphragm. The diaphragm has a preformed working annulus in the shape of a torus of section radius R, whose opposite walls are of semi-circular cross section, each on an arc of about 180°, the double rim 6 lies at the outer periphery of the annulus, and the web 7 lies at the inner periphery of the annulus and spans the internal diameter ID of the working annulus. Assuming usual operating conditions, in which the web is held planar throughout its stroke S, the outlines of Fig. 3 indicate the sectional configuration of a pump cavity in which the diaphragm works with zero clearance, and correspondingly represent in outline the extreme positions of the diaphragm at the ends of its strokes. The outline includes opposed circular flat central portions opposite the web 7 of the diaphragm, and annular sections opposite the working annulus of the diaphragm which are deeply arcuate so that they conform to the torus walls 12 and 13 at the ends of its stroke, as indicated in Fig. 4.

The diametrically opposite circular sections of the torus of the diaphragm are on centers spaced a distance P equal to the sum of the internal diameter ID of the torus plus twice the radius R of the torus cross-section. Desirably, the torus section radius R is selected in relation to the desired stroke; and for a fixed stroke S and correspondingly fixed torus radius R, the effective displacement may be varied by varying the internal diameter ID of the torus.

The desirable size of the torus cross-section depends largely on the selected stroke S, and depends also on the selected conditions with respect to elongation of the walls and compressibility of the filling. I desirably use a torus of minimum cross-sectional area consistent with the selected conditions, for by thus reducing the radius R of the torus, I reduce the overall dimensions of the diaphragm.

As the diaphragm moves from its mid-position shown in Fig. 3 to its extreme position shown in Fig. 4, the walls 12 and 13 of the working annulus remain deeply arcuate in cross-section, but the torus section changes from circular, as in Fig. 3, to a somewhat elongated shape as in Fig. 2. With strokes of predetermined limited length, however, such change of cross-sectional shape involves no substantial change in volume; and conversely, assuming a constant volume, as of incompressible liquid filling, such change in shape involves no substantial elongation of the arcuate walls of the torus. The elongation of the torus walls 12 and 13 consistent with a constant volume throughout different strokes is shown in the following table:

Table

Torus cross-section diameter	Stroke	Percent Elongation
1.0	.25	.00
1.0	.50	.04
1.0	1.00	.68
1.0	1.25	1.52
1.0	1.50	2.92

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The relatively small percentage of elongation, or the corresponding small change in volume if no elongation is permitted, are readily provided for in any of a number of ways. For example, the volume of the filling 25 may be controlled to that required at the ends of the stroke, and a slight compression of the torus walls 12 and 13 may be permitted at the mid-point of the stroke. Alternatively, the filling 25 may be made sufficiently compressible, as by including a small proportion of gas in a liquid filling. Preferably, however, I limit the stroke to that which will produce not more than about 2% theoretical elongation—to a stroke S about 1.25 times the torus section diameter 2R—in which case, the suitably flexible materials of the diaphragm will ordinarily have sufficient elongation characteristics that no special provisions for elongation or compression need be made. This is the case, for example, with a fabric reinforced perbunan rubber diaphragm as of Fig. 2, filled with kerosene at a pressure of about ½ pound per square inch.

In the operation of a diaphragm as indicated in Figs. 1 to 4, the walls of the working annulus of the diaphragm are always maintained taut or substantially taut, and there is substantially no lost motion. During a stroke, the force of the working medium against the leading wall of the working annulus is transmitted through the filling to the opposite or trailing wall of the working annulus. Throughout the operation, such walls always have a deeply arcuate shape, of full or approximately semi-circular cross-section, and never approach flatness. In consequence, the stress on such walls remains substantially proportional to the working pressure of the medium, and can never rise excessively. Because of this, it is possible both to avoid lost motion and a flabby diaphragm at the mid-points of the stroke and to avoid excessive stress on the diaphragm at the end of its stroke.

The pump shown in Figures 5 to 12 inclusive has a front casing 30 and a rear casing 40 joined by peripheral flanges 39 and 49 against opposite sides of the rim 55 of the diaphragm 50. The diaphragm 50 embodies features as set forth above and is made from a front shell 52 and a rear shell 53, each pre-formed with an annular working portion of semi-circular cross-section, and disposed face-to-face to form a toroidal working annulus which is filled with liquid 54.

The two shells of the diaphragm 50 are desirably molded of flexible material which is substantially inelastic but which is capable of some elongation, as to the extent of about 2%. The two shells may be partially cemented together, as over their web area and over all their rim area save for a small filling opening, the toroidal space may then be filled with an inert liquid, for example, water, glycerine, kerosene, oil, or the like, and the assembly then completely cemented. The diaphragm thus pre-assembled is mounted in the pump as a unit, with its rim firmly held between the flanges 39 and 49 of the casings 30 and 40, and its web 56 firmly supported between a pair of circular plates 57 clamped together between a shoulder 36 on the operating shaft 35 and a nut 46 on the reduced threaded end 45 of that shaft 35.

A central boss 31 on the front casing 30 slidably receives the operating shaft 35, which is connected to an operating lever 27 for actuation by the handle of an operating arm 28. A pair of links 22 supported by a pivot pin 23 on opposite sides of a forward projecting tongue 24 below the boss 31 provide a movable fulcrum for the lower end of the operating lever 27. Reciprocation of the arm 28 reciprocates the shaft 35 to carry the web 56 of the diaphragm through any desired range of the working stroke. Full stroke operation carries the web 56 from the extreme rearward position shown in Fig. 5 forward through the intermediate position shown in Fig. 12 and thence to an extreme forward position against the inner face of the front casing 30.

The central section of the front casing 30 forms a planar inner face 32 to conform with the surface of the front

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plate 57 of the diaphragm assembly, with an annular groove 33 at its outer edge to receive the up-turned rim of such plate 57. The annular portion of the casing between such groove 33 and the peripheral flange 39, has an inner surface 34 of arcuate cross-section to fit the wall 52 of the working annulus at the extreme forward end of the diaphragm stroke.

The rear casing half 40 has a central boss 41 formed to slidably receive the nut 46 on the end of the operating shaft 35, and has an inner configuration corresponding to that of the front casing, with a central planar portion 42, a groove 43 to receive the up-turned rim of the rear web plate 57, and an annular portion of arcuate cross section to fit the rear wall 53 of the working annulus at the rear end of its stroke.

The pump is double-acting, and has a front displacement space in front of the diaphragm and a rear displacement space behind the diaphragm.

Inlet and outlet passageways for the front displacement space are formed as follows: At the bottom of the pump, and offset from its vertical center line, (to the right in Fig. 6), a boss 37' is formed to provide an intake 37 to the front displacement space of the pump, in open communication through a passageway in the rims of the casings and the diaphragm with an inlet valve chamber 47 in the rear casing 40 shown in Fig. 7. At the top of the front casing 30, and offset on the opposite side of the vertical center line from the intake 37, a boss 38' forms a discharge 38 from the front displacement space of the pump, leading through openings in the rims of the casings and the diaphragm to a transfer passage 48.

Fig. 7 shows the pump from the same point of view as Fig. 6, with the front casing half 30 and the diaphragm assembly removed, and shows the relative positions of the inlet and outlet passageways for the rear displacement space of the pump. The inlet valve chamber 47 for the front displacement space appears at the bottom of Fig. 7 offset to the right from the vertical center line, as in Fig. 6. At the opposite side of the vertical center line therefrom, the casing 40 forms a combined valve chamber and intake 60, in a boss 61. The transfer passageway 48 from the front displacement space appears in Fig. 7 at the top, offset to the left of the vertical center line. On the opposite side of the center line therefrom, the casing 40 forms a discharge 64, in a boss 65. The intake 60 and discharge 64 communicate with the rear displacement space as shown in Fig. 12.

The pump is mounted on an intake manifold 70, shown in Fig. 5 as connected to a tank 71 and supported thereby. A header space 72 in the manifold 70, which desirably contains a screen 79, communicates separately with each of the valve chambers 47 and 60, through inlet valve inserts 74 in the rear casing 40, and the valve chambers 47 and 60 are each formed with radial ribs 76 to guide inlet valve balls 75 to seating engagement on top of such inserts 74. In addition, in valve chamber 60, there is an overlying rib 77 to prevent displacement of the ball 75 from its seat.

An outlet manifold 80 is mounted on top of the pump, and may carry a discharge hose 81. Such manifold is formed with two sets of radial ribs 86 to guide outlet valve balls 85 into seating engagement on inserts 84 mounted in the upper ends of the transfer passage 48 and the discharge 64. Desirably, the valve inserts 74 and 84 are held in place and in sealing engagement with sealing rings 78 and 88, by engagement of the edges thereof by the inner edges of the manifolds 70 and 80.

The manifolds 70 and 80 may be identical with the fittings 3 and 4 of Fig. 1, and the ends of the casing 40 may be made to receive valve plates 14 of Fig. 1. The flap valves of Fig. 1 may thus be employed with the casing arrangement of Figs. 5 to 12, which I prefer.

Operation of the pump of Figs. 5 to 8 is as follows: As the handle is pulled forward from the position shown in Fig. 5, it draws the web of the diaphragm forward,

and the contents of the front displacement space are discharged upward through the discharge 38 to the transfer passageway 48, thence through the associated valve and out the discharge hose 81. Meanwhile, the rear displacement space undergoes its suction stroke, to draw liquid from the tank 71 upward through the manifold 70 and through the valve to the chamber 60 and thence to that rear displacement space. Upon a subsequent rearward stroke of the diaphragm, the contents of the rear displacement space are discharged upward through the outlet passageway 64 and its associated valve, to the outlet manifold 80. During these working strokes, the working annulus of the diaphragm moves with a rolling motion and undergoes a change in cross-sectional shape, from the extreme position and shape shown in Fig. 5 to the intermediate position and shape shown in Fig. 12 at the mid-point of the stroke, and then on to an extreme forward position, where again it is elongated, in a shape corresponding to that shown in Fig. 5.

During each stroke, as to the left from the position shown in Fig. 5, the medium being pumped exerts a working pressure tending to collapse the leading wall of the toroidal working annulus. Such collapsing, however, is prevented by the filling 54, supported by the trailing wall of the annulus, and ineffective lost motion does not occur. Such trailing wall, which takes the load, always has a deeply arcuate shape of relatively short radius and is not pulled toward straightness to any considerable extent, so that the stress imposed upon it is always substantially proportional to the working pressure.

Instead of a liquid filling, shown in the diaphragms described above, I also found it suitable to employ a solid filling. Thus, for example, as shown in Fig. 9, I have used a rubber ring 90 pre-formed to fit the toroidal cavity of the same diaphragm shells 52 and 53 used with a liquid filling in the pump of Figs. 5 to 8. Such ring 90 may be of solid rubber and hence incompressible, or may be of rubber containing some voids. In either event it is of such consistency and so cured that it is readily deformable as the diaphragm moves through its stroke. If desired, the ring may be cemented in the diaphragm assembly, to avoid any possibility of wear between it and the shell walls.

Figs. 13 and 14 show modified diaphragm constructions. In Fig. 13, the diaphragm is made of two complementary annular shells 92, each formed to provide a substantially semi-circular wall for the working annulus of the diaphragm, with radially extending rims at both the inner and outer peripheries thereof. In this case, such two shells are secured in face-to-face relationship against opposite sides of an annular rim spacer 93 and a circular web spacer 94. The outer rims are of course held against the spacer by being clamped between flanges of the pump casing, and the inner rims are secured against the opposite faces of the web spacer by a pair of clamping rings 95, conveniently fastened by flat headed rivets.

The diaphragm shown in Fig. 14 is made of two complementary shells 96 each of which has an annular working portion and flat walls at both its inner and outer peripheries. The two shells are joined face-to-face as by cementing, and the annular cavity is suitably filled. As indicated by the somewhat accentuated showing of this figure, the annular working portion of the diaphragm may have opposite walls of slightly more than a semi-circular cross section. With such configuration, the shape of the working annulus passes through a truly circular shape at an intermediate point between its central position and its extreme position at each end of its stroke, so that it is slightly flattened radially at the central position, and correspondingly, it may be elongated at the ends of its stroke to a somewhat less extent than is the case with the other modifications.

I claim as my invention:

1. In a diaphragm device having a casing and an operating member reciprocable with respect to the casing

through a stroke of predetermined length, a diaphragm structure comprising a central piston portion carried with the operating member and spaced radially from a surrounding casing portion, an annular working portion connected at its inner and outer peripheries respectively to said piston portion and said casing portion, said working portion including axially opposite walls outwardly convex with respect to each other and each extending in section directly from said piston and casing portions through an arc of substantially 180° between its inner and outer peripheries, filling means contained between said walls and mutually supporting each from the other, said predetermined stroke length being between 1 and 1.25 times the wall-section diameter.

2. A diaphragm pump, comprising a diaphragm structure having a working annulus, said working annulus having axially opposite flexible outer walls outwardly convex and of substantially semi-circular cross-section, a deformable filling contained in said annulus and providing mutual support between said walls, a support for the outer periphery of said annulus, a support for the inner periphery of such annulus, means for relatively reciprocating said supports axially of the annulus through a stroke not exceeding about 1.25 times the section diameter of said outer walls, and a casing defining a displacement space between itself and said diaphragm structure and formed to present an inner surface substantially conforming with said diaphragm structure at the end of its limited stroke.

3. A diaphragm pump adapted for high suction lift, comprising a casing forming a displacement chamber, a valved inlet and valved outlet for said chamber, an operating member reciprocable axially of the chamber through a stroke of predetermined length, a diaphragm structure having a central piston portion carried with the operating member, a peripheral diaphragm support spaced radially from and surrounding the piston portion, an annular working portion for the diaphragm connected at its inner and outer peripheries respectively to the piston portion and the support, said working portion having axially opposite walls outwardly convex with respect to each other and each extending in section through an arc of substantially 180° between its inner and outer peripheries, filling means contained between the walls and supporting the wall facing the displacement chamber in outwardly extended position throughout the stroke, the predetermined stroke length being not more than 1.25 times the wall-section diameter, said displacement chamber having an outwardly disposed wall springing from said diaphragm support at the outer periphery of the working portion and substantially conforming to said chamber-facing diaphragm wall in its outwardly extended position at the end of the stroke, said outwardly disposed chamber-wall being joined by walls substantially conforming to the piston portion of the diaphragm at the end of the stroke, the chamber-facing wall of the working portion on a pressure-stroke being pressed by said filling and the opposite working-portion wall into close clearance relation with said conforming wall.

4. In a diaphragm device having a casing to support the outer periphery of a diaphragm and defining displacement spaces on opposite sides thereof and having an axially reciprocable support for the inner periphery of the diaphragm and reciprocable through a predetermined displacement distance in opposite directions from its central position between said displacement spaces, a double-acting diaphragm comprising a closed toroidal working annulus with axially opposite walls of arched configuration and supported in outwardly convex relation in substantially semi-circular arcs, the predetermined displacement distance being not more than 1.5 times the radius of the wall-section arcs to maintain said walls in deeply arched configuration throughout the diaphragm stroke and to avoid substantial change in volume within said annulus during the stroke.

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5. In a double-acting diaphragm pump having a casing forming a pair of opposite displacement chambers each provided with inlet and outlet valve means, and having an operating member reciprocable in the casing through a stroke of predetermined length, a diaphragm structure 5 comprising a central piston portion carried with the operating member and disposed between the chambers and spaced radially from a surrounding casing portion, an annular working portion connected at its inner and outer periph- 10 eries respectively to said piston portion and said casing portion, said working portion having axially opposite walls outwardly convex with respect to each other and each extending in section through an arc of substantially 180° between its inner and outer peripheries, filling means 15 contained between said walls and mutually supporting each from the other, the predetermined stroke length being not more than 1.25 times the wall-section diameter.

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6. In a double-acting diaphragm device as set forth in claim 5, a diaphragm structure as defined therein in which the stroke length is between 1 and 1.25 times the wall section diameter.

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