March 10, 1964 R. N. HARDY 3,124,078

REFLEX DIAPHRAGM PUMP

Filed Nov. 15, 1960 4 Sheets-Sheet 1

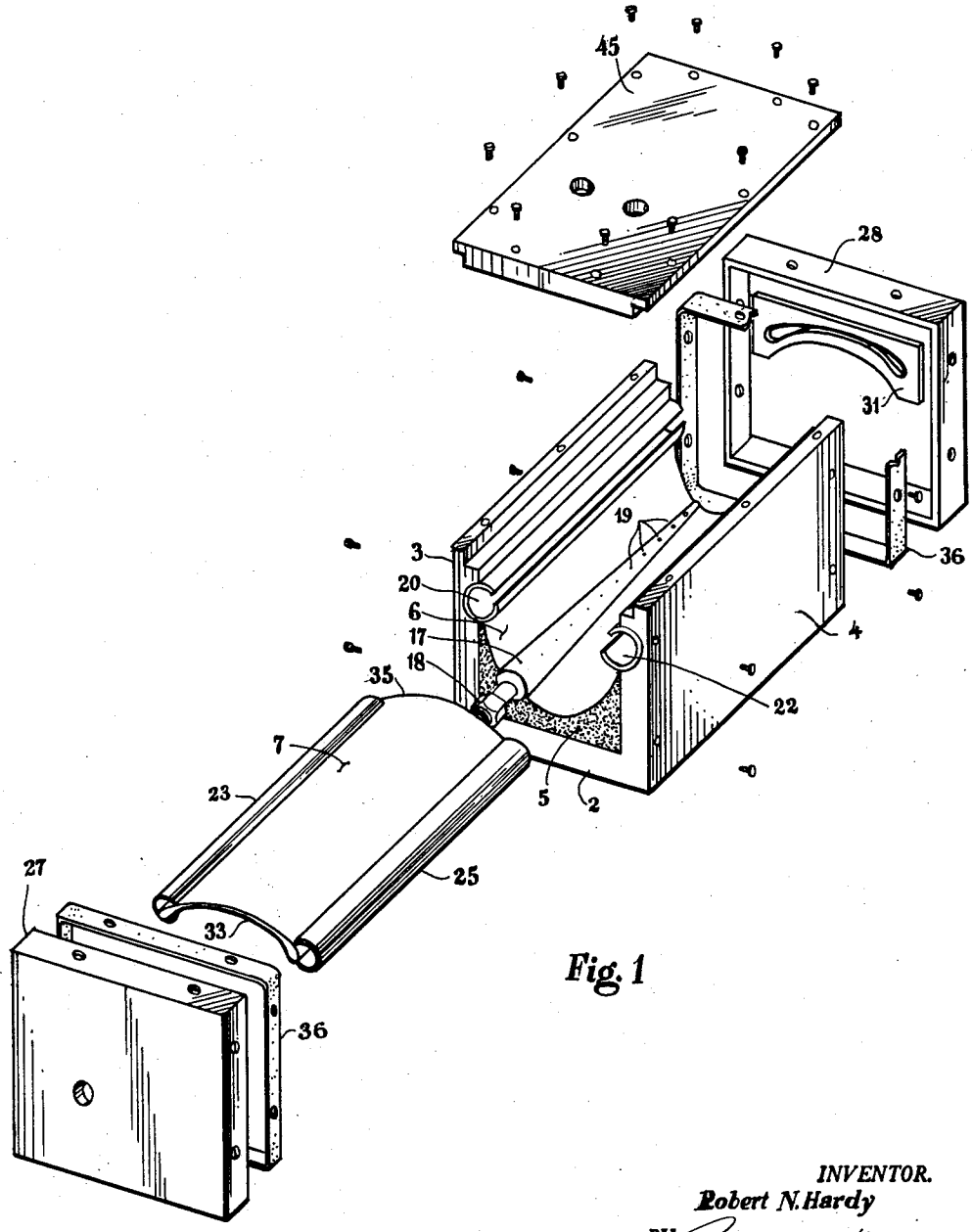

Fig. 1

INVENTOR.
Robert N. Hardy
BY
Attorney

March 10, 1964 R. N. HARDY 3,124,078

REFLEX DIAPHRAGM PUMP

Filed Nov. 15, 1960 4 Sheets-Sheet 2

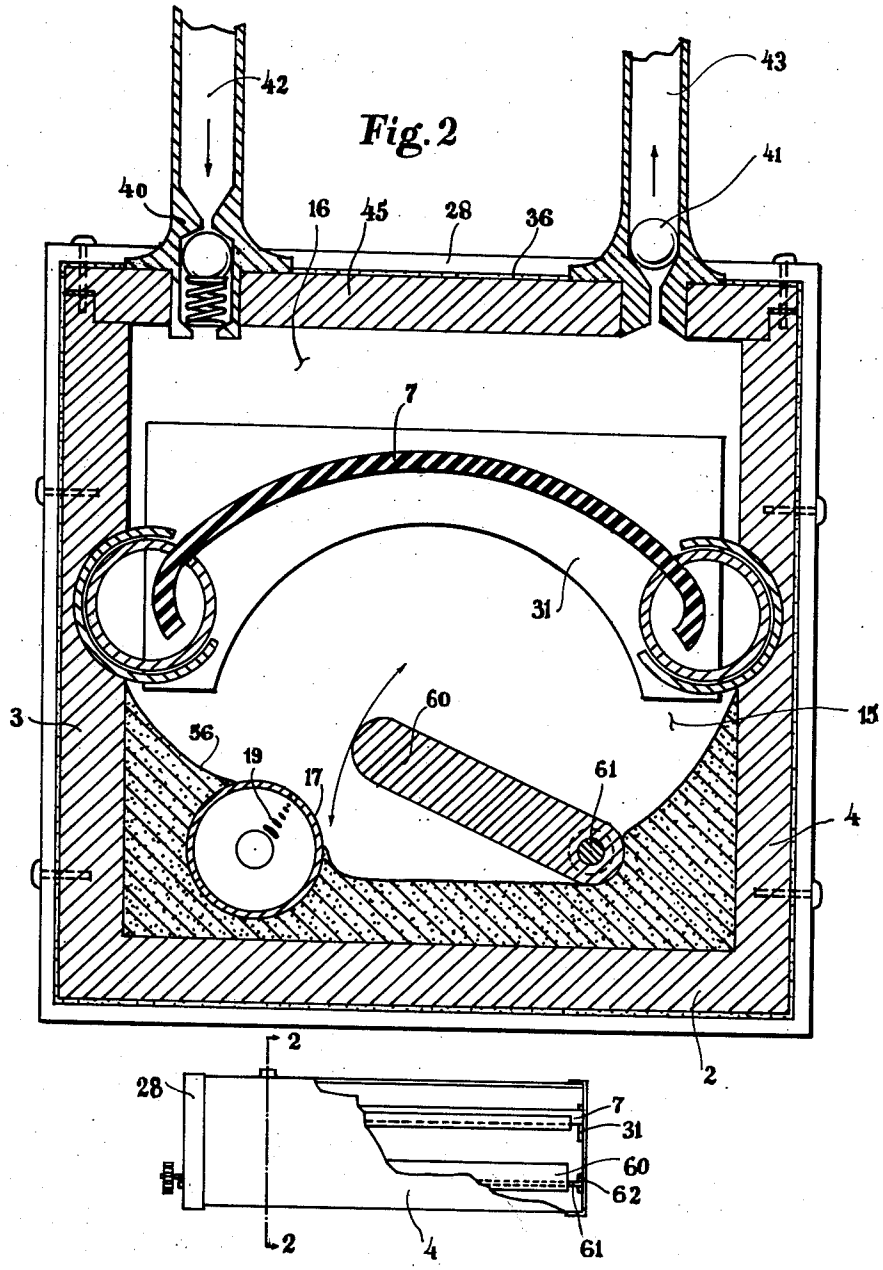

Fig. 2

Fig. 2A

INVENTOR.
Robert N. Hardy
BY
Richard N. Hardy
attorney

March 10, 1964 R. N. HARDY 3,124,078

REFLEX DIAPHRAGM PUMP

Filed Nov. 15, 1960 4 Sheets-Sheet 3

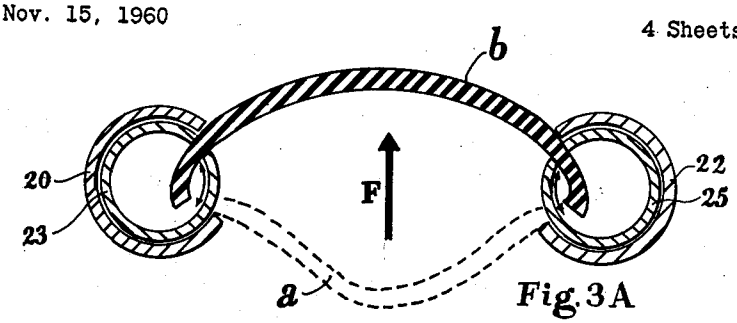

Fig. 3A

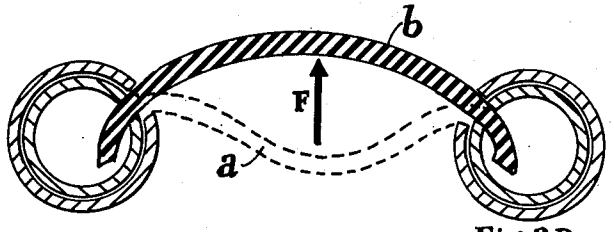

Fig. 3B

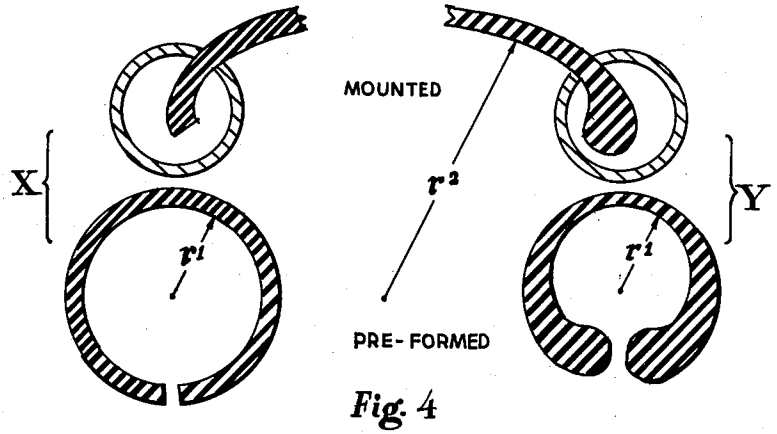

Fig. 4

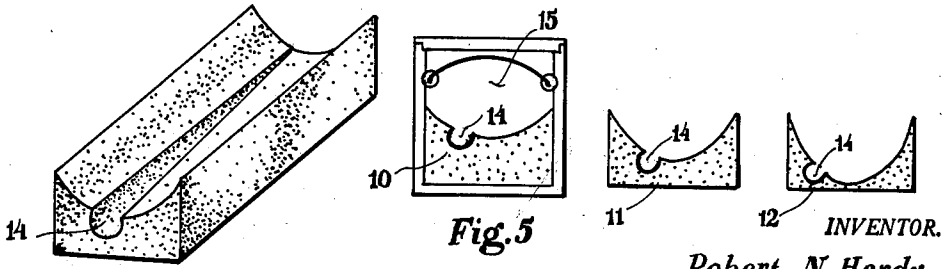

Fig. 5

INVENTOR.

BY Robert N. Hardy

Attorney

March 10, 1964 R. N. HARDY 3,124,078

REFLEX DIAPHRAGM PUMP

Filed Nov. 15, 1960

4 Sheets-Sheet 4

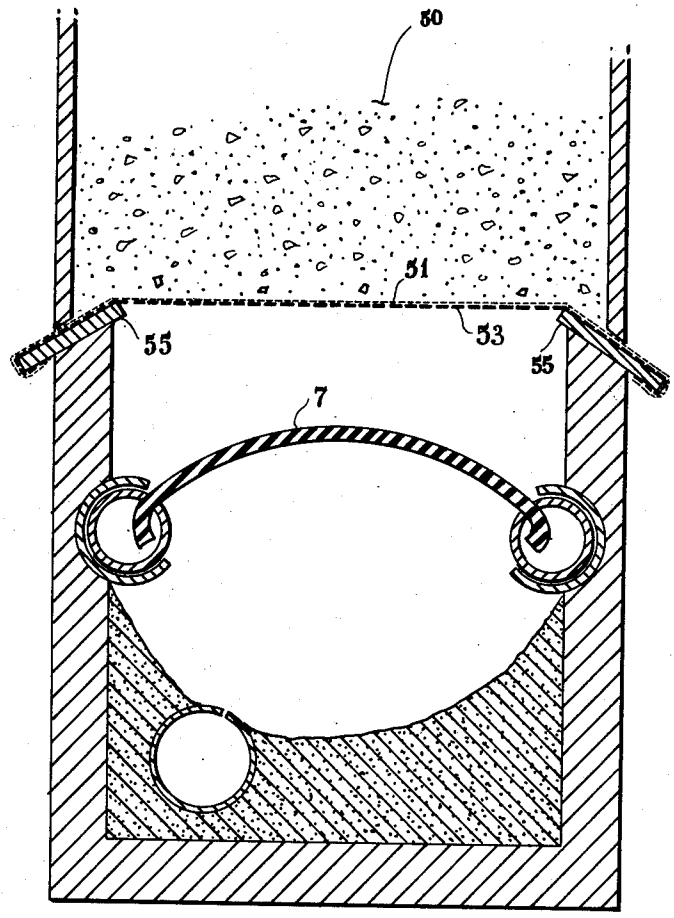

Fig. 6

INVENTOR.
Robert N. Hardy
BY
Richard M. Hauer
Attorney

United States Patent Office 3,124,078 Patented Mar. 10, 1964

3,124,078

REFLEX DIAPHRAGM PUMP

Robert N. Hardy, Colorado Springs, Colo., assignor, by mesne assignments, to MBM Mineral Industries, a corporation of Arizona

Filed Nov. 15, 1960, Ser. No. 69,438
9 Claims. (Cl. 103—152)

This invention relates to pressure transducers and more particularly to pumps of the diaphragm type for the compression and displacement of liquids and gasses, having a diaphragm oscillably mounted in a chamber and dividing the chamber into two parts, the one chamber being filled or vacated to impart movement to the diaphragm, the other containing the substance on which the moving diaphragm acts to produce the compression or displacement.

Heretofore, the diaphragms of the general type of pump here being considered have been manufactured from rubber or metal or other resilient material and have been mounted in a generally flat position within the pumping chamber. Actuation of these diaphragms has been either by direct connection with a connecting rod and crank shaft which reciprocates the large area diaphragm or by contact with an auxiliary liquid which flows under the action of a pump piston which, in its reciprocations, is adapted to suck and discharge said auxiliary liquid, which thus acts on the face of the diaphragm to impart reciprocatory motion thereto. Actuation may also be produced by vacating the air or other gas from the actuating chamber contiguous to the diaphragm, thus distorting the resilient diaphragm and allowing it to return to its normal pose when the pressure is returned to normal within the chamber. The latter type of device, generally known as a vacuum pump, is relatively slow acting and possesses a restoring force proportional to the elasticity of the material of which the diaphragm is constructed and to the diaphragm tension produced on mounting the diaphragm. The greater the tension across the diaphragm the greater will be the vibratory tendency when the diaphragm is released to its normal position.

For applications which require a fluid displacement of a high frequency, the pumps of the prior art will not provide the requirements.

It is therefore the primary object of the apparatus of the present invention to impart a high velocity flow to the fluid being pumped.

A further and associated object of the invention is to create a reflex acting pump diaphragm having great speed on the pumping stroke and a very minimum of damping vibration.

A still further object of the diaphragm employed in the apparatus of the present invention is to "snap back" into normal position when a certain minimal vacuum pressure exists on one side of the diaphragm.

A still further object of the invention is to prolong the useful life of the pump diaphragm by a novel mounting. Other and still further objects of the present invention will become apparent by a reading of the description taken in conjunction with the attached drawings.

With these objects in view, the present invention essentially consists of mounting a resilient diaphragm over the activating chamber of a diaphragm type pump, the diaphragm being mounted in an arched position so as to present a concave surface to the activating chamber, and the diaphragm having a natural intrinsic tendency to curl and thereby to decrease the radius of the said concave surface.

The accompanying drawings illustrate, by way of example, several embodiments of the invention.

FIGURE 1 is an exploded view of the preferred embodiment of the pump having a pumping chamber for fluids above the diaphragm.

FIGURE 2 is a cross sectional view of the pump taken midway the length thereof showing a modification of the diaphragm mounting means to provide a movable diaphragm mounting, and also illustrates a rotatable cam for modifying the lengths of the diaphragm pumping stroke.

FIGURE 2A is a side view of the pump shown in FIGURE 2.

FIGURE 3A shows the two extreme positions of a diaphragm having an oscillatory mounting.

FIGURE 3B shows the two extreme positions of a diaphragm having stationary mounting.

FIGURE 4X illustrates the pre-formed shape of a diaphragm having constant cross sectional thickness with given radius, and the greater radius of the diaphragm in its mounted position.

FIGURE 4Y illustrates the pre-formed shaped of a diaphragm of the preferred embodiment having non-uniform cross sectional thickness with given radius, and the greater radius of the diaphragm in its mounted position.

FIGURE 5 illustrates the changeable filler units which may be inserted into the pump as the preferred method of modifying the pumping stroke length.

FIGURE 6 is a modification of the more conventional type of pumping chamber, showing a screen mounted over the diaphragm, on top of which is placed aggregate material which is to be subjected to the air forces produced by the moving diaphragm.

In the embodiment illustrated in FIGURE 1, the pump comprises a base housing member 2, which may be rectangular in shape in its plan view. Extending upward at right angles from the rectangular bottom plate of the base are two sides 3 and 4 parallel with each other and forming a channel-like open-ended container. Disposed within the channel is a filler substance 5, having a smooth concave top surface 6 conforming substantially to the full extended deformed curvature of the resilient diaphragm 7, which is mounted above the filler, as will be more fully described.

The filler 5, in addition to its function of occupying space within the base member to reduce the space which must be vacated in the activating chamber 15 also regulates the extent of downward travel of the diaphragm 7, by the distance between the diaphragm and the filler. FIGURE 5 illustrates several different configurations of fillers 10, 11 and 12, which may be inserted into the base channel member depending on the length of the diaphragm pumping stroke which is desired. The filler 10 having the least concave upper surface would restrict the diaphragm travel and the pumping volume the greatest.

In the filler element which is inserted into the base channel member 2 is a longitudinal conical shaped hole 14, having a small portion of its top side exposed to the activating chamber 15 of the pump. This exposure to the activating chamber establishes communication between the chamber and the tuned manifold 17, which is inserted into the hole 14, and attached to a source of vacuum pressure. To insure proper distribution of vacuum pressure throughout the activating chamber, the manifold, having the shape of a truncated cone, extends the entire length of the chamber and is provided with breather holes 19 on the surface of the manifold, the hole at the extreme large diameter end of the manifold being the smallest in size with the holes gradually becoming larger in size toward the small diameter end of the manifold. The small end of the manifold is sealed and the large diameter end is fitted with appropriate means 18 for connection to a source of vacuum pressure.

For mounting the pump diaphragm 7, there are secured to the top of the long sides 3 and 4 of the rectangular base member, two right cyclindrical tubes 20 and 22,

which act as rotor bearing housings, one mounted on each side of the base member and each tube having removed therefrom a thin slot extending the entire length of the tube, said slot having straight parallel sides and each side being at right angles to the base of the cylinder. The cylinders are constructed from material which will provide rigidity to the cylinder after the slot is removed. The slots are positioned in the two cylindrical housings so that they face each other across the base member, each slot having its center line approximately 22° above the flat plane bisecting the two cylindrical tubes.

Telescoped into the two aforementioned cylindrical housing tubes 20 and 22, are two smaller diameter clamping tubes 23 and 25, one in each of the larger tubes, the clamping tubes having an outside diameter approximately equal to the inside diameter of the larger bearing or housing tubes with some small tolerance for easy slippage and relative rotation between the two tubes. Each of the interior clamping tubes are also provided with a slot similar in size and description to the slots in the housing tubes. Inserted into the slot of the inside tubes is the straight edge of a resilient diaphragm member 7, which comprises the oscillatory member of the pump. The width of the slot in the inside bearing tube is less than the thickness of the diaphragm, the inside tube thereby providing a grip or hold on the edge of the diaphragm, thus rigidly securing the entire edge of the diaphragm to the side of the base member 2.

Before describing the complete mounting of the pump diaphragm, the nature of the diaphragm itself must be understood. In order to provide high speed reflex action in the diaphragm of this pump, the diphragm is prefabricated in a substantially cylindrical shape of the given radius. In the preferred embodiment of the present invention, the diaphragm is constructed of latex rubber and is pre-formed in a cylindrical mold having an approximate radius of

$$\frac{X}{2\pi}$$

where X equals the approximate distance between the inside edges of the two housing cylinders 20 and 22 on the sides of the base member. The preformation of the diaphragm as shown in FIGURE 4, establishes the molecular structure of the diaphragm in such a fashion that the diaphragm will, in its normal mounted position, constantly possess a tendency to return to its originally formed shape, or in other words have a natural biasing action toward a configuration of smaller radius, r. When mounted on the pump base member 2, the pre-formed diaphragm is distorted from its pre-molded shape into an arc of larger radius, r_2, and is clamped to both sides of the pump base member 2 in such a fashion that the aforesaid arc in the diaphragm is self-maintained. Thus the natural tendency of the edges of the diaphragm to come together into the pre-formed molded shape gives the center of the diaphragm a radial component of force F to return from a position of depression "a" within the actuating chamber 15 at an increasing velocity to its outermost mounted position "b." It should be pointed out that the velocity of the reflex diaphragm increases as the diaphragm moves outwardly, with the greatest velocity occurring near the end of travel. Such a concept distinguishes the reflex diaphragm from those diaphragms of other types which possess velocity characteristics similar to that of a bow string where the highest rate of velocity occurs at the furthest point of distortion or pull and decreases as the string nears its normal position. A depression of the diaphragm is obtained when the pressure beneath the diaphragm becomes sufficiently less than the pressure on the top or convex side of the diaphragm. The great reflex action of the rubber diaphragm in returning to its original mounted position produces a high velocity in the fluid being acted upon on the top side of the diaphragm.

Over each end of the pump base member is secured an end cap 27 and 28, which is attached to the base 2.

Mounted by cement or other appropriate means to the inside surface of each end cap is a resilient sealing seat 31. A portion of the seat is removed and imitates the shape and dimension of the width of the mounted pump diaphragm 7. When the end caps are in place the protruding ends 33 and 35 of the diaphragm 7 are received into the slots in their respective sealing seats, thus providing an air tight resilient seal between the pump activating chamber 15 and the pumping chamber 16. A gasket 36 of a type well known in the art is mounted between the surfaces of the pump base and top members and the mounting flanges of the end caps to maintain an air tight seal between the outside air pressure and the activating and pumping chambers.

Referring now to the pumping chamber 16, the embodiment of the present invention shown in FIGURE 2 illustrates a conventional valving arrangement of an inlet check valve 40 and an outlet check valve 41 in the suction and delivery lines 42 and 43 of the system in which the pump is incorporated. The inlet and outlet valves are mounted in a top cover plate 45, which defines a closed chamber 16 over the pump diaphragm 7. The top plate is attached to the sides and end caps of the pump base member and with appropriate gaskets and holding means forms an air tight pumping chamber 16.

In the second embodiment of the pump of the present invention, as shown in FIGURE 6, the top cover plate 45 and valves are removed and the pump diaphragm is exposed to an opened top chamber 50, which may be adapted to receive material upon which it is desired to exert cyclic air forces.

In lieu of the top cover plate 45 and valves of the pump, a fine gauge wire screen 51 is supported over the diaphragm 7 by a coarse gauge reinforcing screen 53, both of which are brazed to an inclined extension 55 of the sides of the pump base member. The two supporting screens are pervious to the air being pumped by the diaphragm, yet act in cooperation with the walls of a chamber to support material which it is desired to stratify by the pressurized air.

In the second embodiment of the mounting means of the resilient diaphragm, as shown in FIGURE 3A, greater volumes may be displaced by each stroke of the diaphragm and longer useful life may be expected of the diaphragm by rotatably oscillating the inner clamping tube 23 and 25 within the outer rigidly mounted housing tube 20 and 22. Rotation of the clamping tube is accomplished by increasing the width of the slot in the outer housing cylinder so that the clamped edge of the diaphragm may traverse an arc around that portion of the circumference of the outer housing cylinder represented by the width of the slot. This movement of the edges of the diaphragm allows the center portion thereof to sink lower into the activating chamber and thus creates larger pumping volumes per stroke. In addition, the rotative movement of the diaphragm edges reduces the degree of bending and fatigue of the edges during the oscillation of the diaphragm and increases the useful life thereof.

As noted in FIGURES 1, 2, and 4Y, the most desired shape of the diaphragm is not uniform in cross sectional width as is the diaphragm of FIGURE 4X. It has been found that increased reflex speeds are possible by reducing the thickness of the diaphragm at its center and increasing the thickness outwardly from the center toward the edges, the portion of greatest thickness being the edge portion inside the clamping tube. This greater shoulder thickness at the edges improves the holding properties of the clamping means as well as increases the reflex speed of the diaphragm.

As a modification of the concept of various shaped fillers which may be inserted into the base channel member 2 for the controlling of the length of the pumping stroke, there is seen in FIGURE 2 a second type of filler 56, having disposed near the concave surface thereof and in a position to be centrally located in the activating

chamber of the pump longitudinally of the base member, a cam **60** supported by a rotatable shaft **61** journaled in mounting bearings **62** on the inside surface of the pump end caps. By controlling the angle of rotation of the cam **60** with a knob or other convenient means, the amount of diaphragm depression can be controlled. If the cam is turned so as to protrude upwards in the activating chamber **15**, the diaphragm **7** cannot be depressed further than the distance the cam is away from the diaphragm in its mounted position. Restriction of the depression movement of the diaphragm reduces the volume of fluid which can be displaced by one stroke of the diaphragm. For full volume output the cam is rotated to a position below the level of greatest diaphragm depression.

Having thus described my invention, what I claim and desire to secure by Letters Patent is:

1. A collapsible chamber motor for the compression and displacement of fluids comprising in combination;
- a base member having a pair of unstanding side walls;
- a concave filler carried by said base member;
- a resilient diaphragm;
- means clamping said diaphragm in an arched configuration to said base member, said diaphragm extending the longitudinal length of the base member and, in cooperation with the concave surface of the said filler, defining a partially enclosed activating chamber;
- the said means clamping the diaphragm further including, a pair of longitudinally slotted housing cylinders, a pair of longitudinally slotted clamping cylinders each of which is concentrically arranged with and journaled for rotation within one of the said housing cylinders, the said housing cylinders being rigidly attached to the upstanding side walls of the said pump base member and the lengthwise side edges of the resilient diaphragm protruding through the longitudinal slots of the inner clamping cylinders, whereby the said diaphragm side edges are tightly held by the inner cylinders and are adapted to move through an arc whose center is the longitudinal axis of the said concentric cylinders and whose length is defined by the width of the slot in the outer housing cylinders, said slots being of greater width than the slots in the inner clamping cylinders;
- end caps secured to said base member at each end thereof completing the enclosure of the said activating chamber; resilient sealing seats mounted on the said end caps and receiving the ends of the said diaphragm, whereby the said activating chamber is air tight;
- a passage lengthwise of the said filler and establishing communication with the said activating chamber;
- a manifold, said manifold disposed within said passage and adapted for connection to a source of vacuum.

2. The combination of claim 1 wherein the resilient diaphragm has a non-uniform thickness across its width.

3. The combination of claim 1 wherein the resilient diaphragm is constructed in a prefabricated tubular configuration of a radius less than the radius of the circle of which the mounted diaphragm is an arc.

4. A motor of the diaphragm type for the compression and displacement of fluids, comprising in combination;
- a base member having upstanding side walls;
- a filler carried by said base member;
- a resilient diaphragm;
- means clamping said diaphragm to the upstanding side walls of the base member in an arc;
- an activating chamber partially defined by said diaphragm and said filler;
- said clamping means further comprising;
  - a pair of longitudinally slotted housing cylinders disposed on the side walls of said pump base member and rigidly attached thereto;

  - a pair of longitudinally slotted clamping cylinders, said clamping cylinders respectively arranged for rotation with respect to the said housing cylinders and disposed in a concentric relationship thereto, said slots of the clamping cylinders receiving and clamping the edges of the said diaphragm; end caps secured to said pump base member;
  - sealing means secured to said end caps and receiving the unclamped ends of the said diaphragm;
  - and manifold means carried by said filler and adapted to establish communication between said activating chamber and a source of vacuum pressure.

5. The combination of claim 4, wherein the said longitudinal slots of the said housing cylinders are of greater width than the slots of the said clamping cylinders whereby the clamped edges of the diaphragm may move through an arc defined by the width of the slot in the housing cylinders.

6. A fluid pump, comprising in combination;
- a casing having a hollow interior;
- a resilient diaphragm mounted within the casing so as to divide the casing interior into two separate chambers;
- inlet and outlet valving means carried by said casing and establishing communication between one of said chambers and the exterior of the casing;
- means connecting the other of said chambers to a source of pressure influence;
- mounting means for securing the diaphragm to the casing including;
  - at least one cylindrical retainer tube securing an edge of the resilient diaphragm;
  - at least one slotted tubular cylindrical bearing member secured to the casing and in which is housed the said retainer tube.

7. A fluid pump, comprising in combination;
- a casing having a hollow interior;
- a resilient diaphragm mounted in a self sustained arched configuration within the casing so as to divide the casing interior into two separate chambers;
- inlet and outlet valving means carried by said casing and establishing communication between one of said chambers and the exterior of the casing;
- means connecting the other of said chambers to a source of pressure influence; and
- a plurality of slotted cylindrical clamping tubes supported by the walls of the said casing having the edges of the diaphragm disposed in the slots of the clamping tubes.

8. A fluid pump, comprising in combination;
- a casing having a hollow interior;
- a resilient diaphragm mounted in a self sustained arched configuration within the casing so as to divide the casing interior into two separate chambers;
- inlet and outlet valving means carried by said casing and establishing communication between one of said chambers and the exterior of the casing;
- means connecting the other of said chambers to a source of pressure influence;
- a plurality of slotted cylindrical clamping tubes supported by the walls of the said casing having the edges of the diaphragm disposed in the slots of the clamping tubes; and
- bearing means for housing said clamping tubes, said bearing means being rigidly secured to the interior walls of the casing.

9. A collapsible chamber pump-motor for the compression and displacement of fluids comprising in combination;
- a base member having a pair of upstanding side walls;
- a concave filler carried by said base member;
- a resilient diaphragm;
- means clamping said diaphragm in an arched configura-

tion to said base member, said diaphragm extending the longitudinal length of the base member and, in cooperation with the concave surface of the said filler, defining a partially enclosed activating chamber;

the said means clamping the diaphragm further including, a pair of longitudinally slotted housing cylinders, a pair of longitudinally slotted clamping cylinders each of which is concentrically arranged with and journaled for rotation within one of the said housing cylinders, the said housing cylinders being rigidly attached to the upstanding side walls of the said pump base member and the lengthwise side edges of the resilient diaphragm protruding through the longitudinal slots of the inner clamping cylinders, whereby the said diaphragm side edges are tightly held by the inner cylinders and are adapted to move through an arc whose center is the longitudinal axis of the said concentric cylinders and whose length is defined by the width of the slot in the outer housing cylinders, said slots being of greater width than the slots in the inner clamping cylinders;

end caps secured to said base member at each end thereof completing the enclosure of the said activating

chamber, resilient sealing seats mounted on the said end caps and receiving the ends of the said diaphragm, whereby the said activating chamber is air tight;

a passage lengthwise of the said filler and establishing communication with the said activating chamber;

a manifold, said manifold disposed within said passage and adapted for connection to a source of vacuum;

means forming a closed pumping chamber over the resilient diaphragm including a cover plate attached to the top edges of the said upstanding side walls of the base member and the said end caps;

said plate having a pair of apertures therein;

an inlet valve;

an outlet valve;

said valves attached to the cover plate and disposed in the apertures therein.

References Cited in the file of this patent

UNITED STATES PATENTS

2,079,858	Horton	May 11, 1937
2,871,789	Kiffer et al.	Feb. 3, 1959
2,948,223	Mashinter	Aug. 9, 1960