

Feb. 18, 1969

M. J. EULL
TUBULAR DIAPHRAGM PUMP

3,427,987

Filed May 15, 1967

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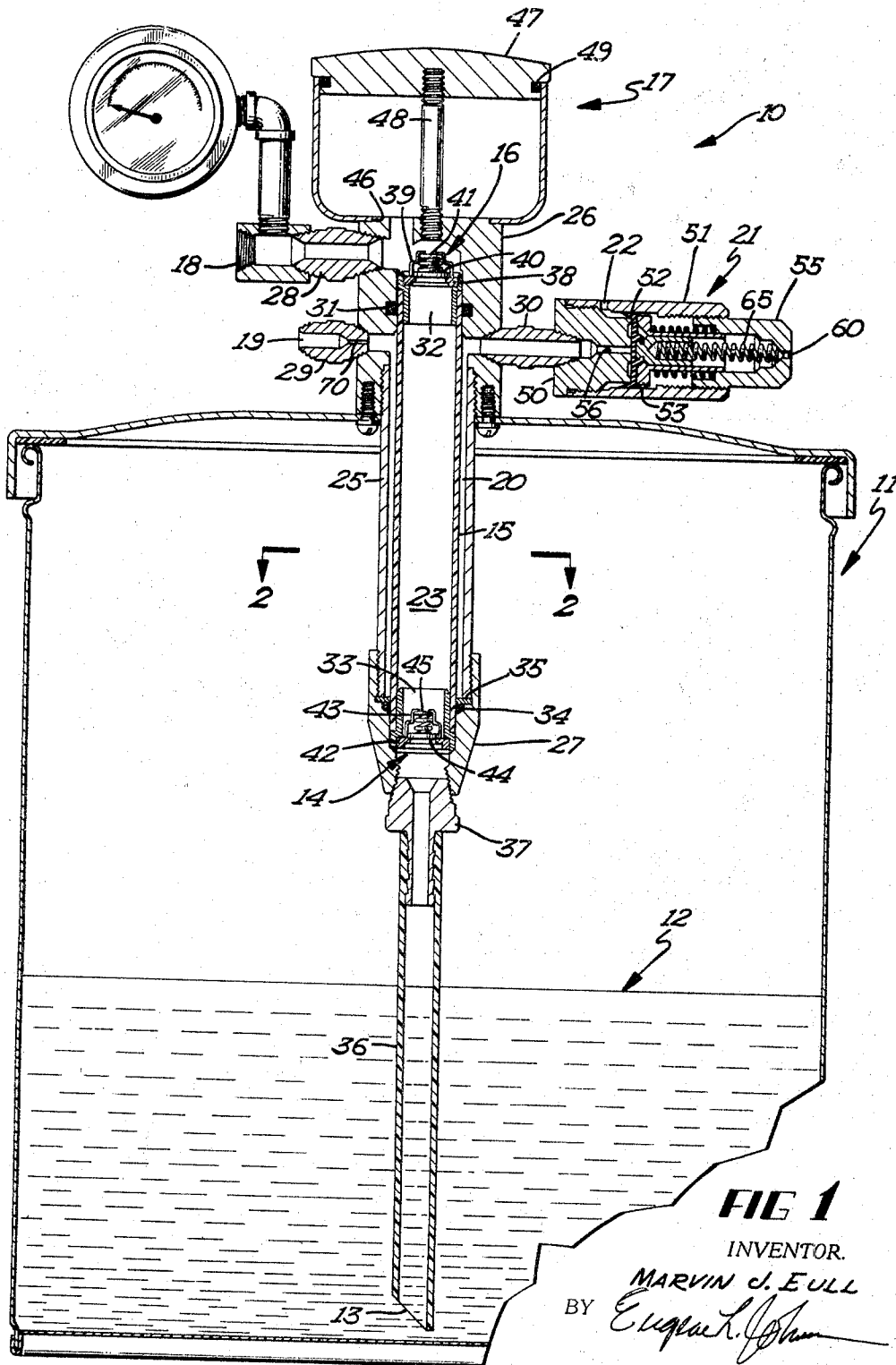


FIG 1

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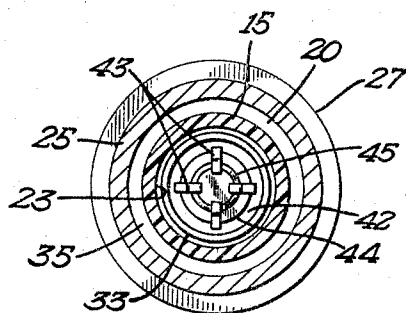


FIG 2

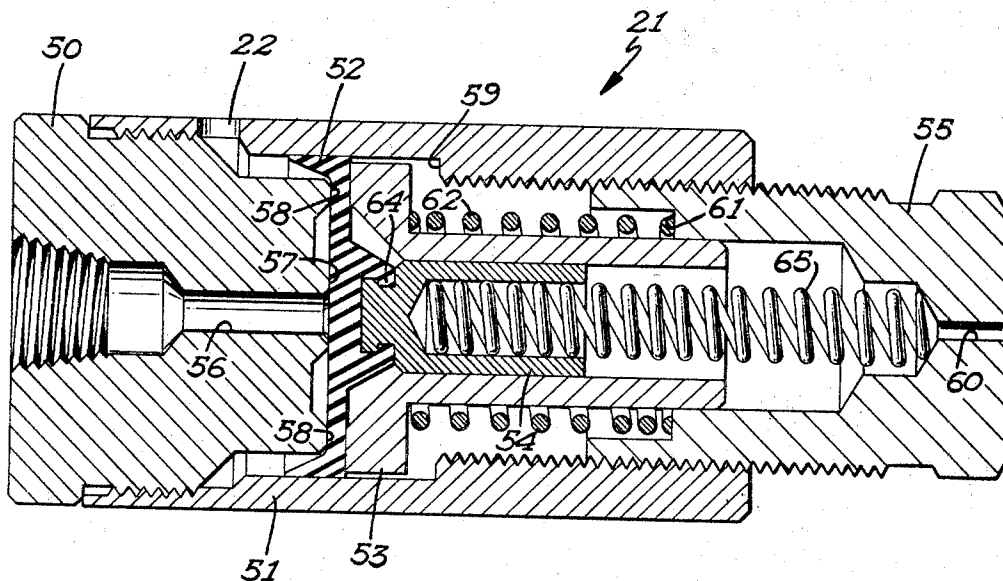


FIG 3

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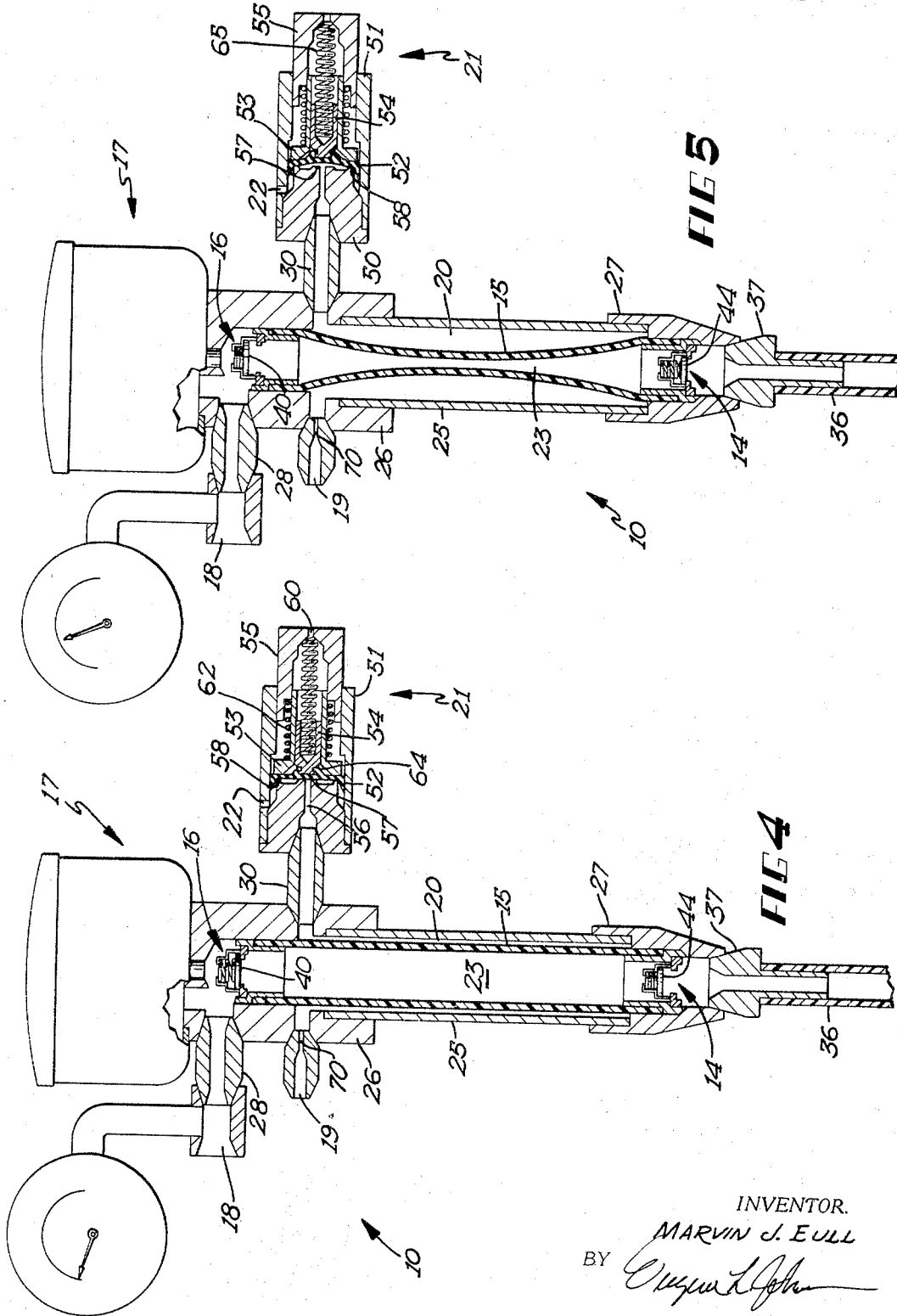
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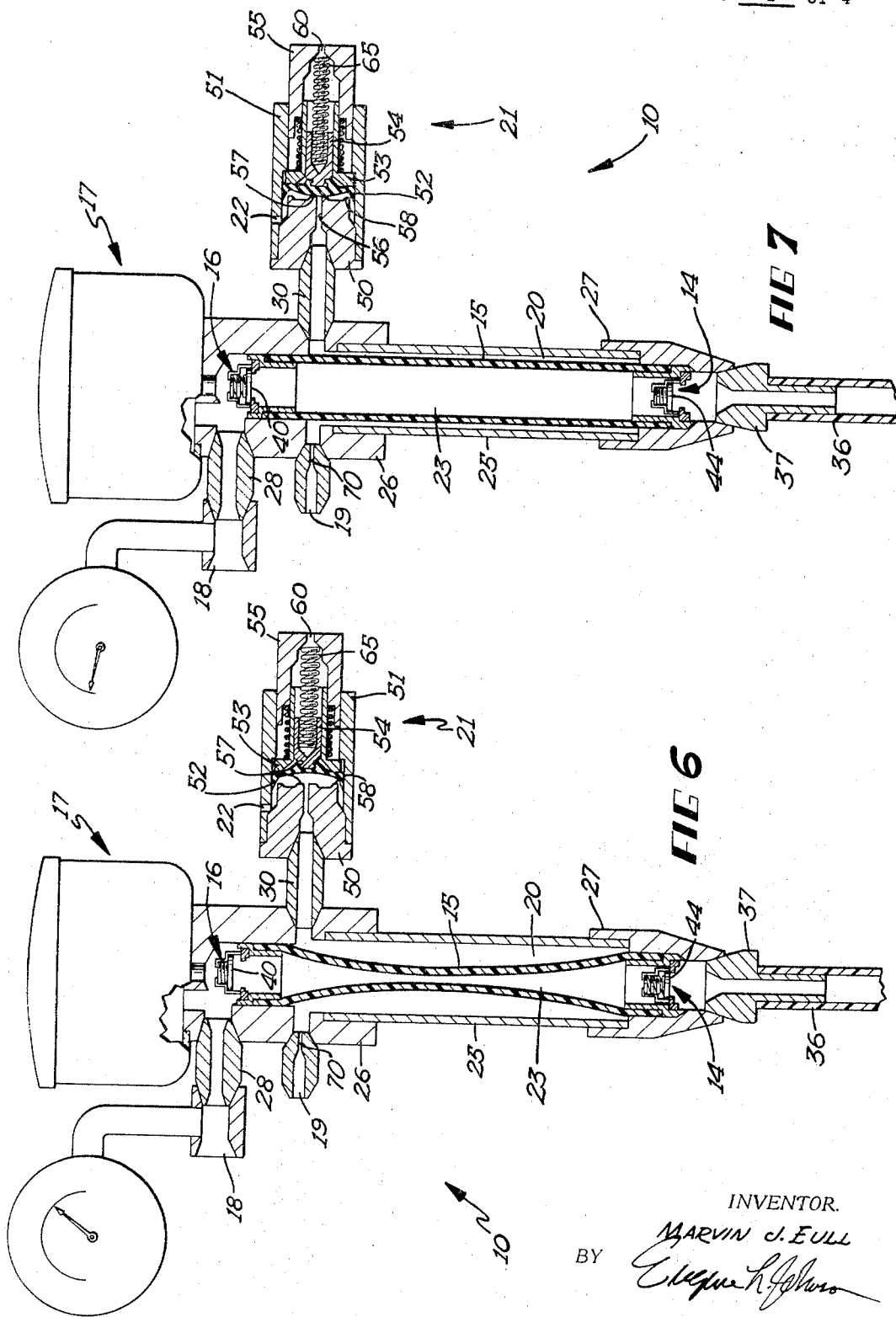
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Filed May 15, 1967

Sheet 4 of 4



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TUBULAR DIAPHRAGM PUMP

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Filed May 15, 1967, Ser. No. 638,389

U.S. Cl. 103—152

Int. Cl. F04b 43/02

8 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a pump having a tubular diaphragm and a two-stage automatically-operating pressure control valve. Air pressure is introduced into a pressure chamber adjacent the tubular diaphragm and pulsation of the diaphragm is caused by cyclically exhausting air pressure from the pressure chamber through the pressure control valve. The two-stage action of the pressure control valve provides a substantial pressure differential in the pressure chamber.

Background of the invention

The invention pertains to air pressure actuated pumps. More particularly, it pertains to such pumps wherein a volumetric change in a tubular diaphragm is brought about by pulsating air pressure acting in a pressure chamber adjacent the diaphragm, to provide the pumping action.

Tubular diaphragm pumps have been provided with various means for controlling air pressure to cause pulsations of the diaphragm. Such art is represented by the patent to Ulbing, 3,194,170, issued on July 13, 1965, and a subsequent patent to Voelker, 3,250,226, issued on May 10, 1966.

The present invention is an improvement over the prior art in that it constitutes a tubular diaphragm pump with a pressure control valve for controlling pulsation thereof which has a minimum of elements, an adjustable pressure chamber exhaust pressure and an unexpectedly high pressure differential in the pressure chamber.

In the operation of tubular diaphragm pumps, the diaphragm is caused to expand and contract when subject to pressure pulsations or differential. When input pressure is taken from a constant pressure source and introduced into the pressure chamber adjacent the diaphragm it becomes necessary to alternately vent and confine the pressure in the pressure chamber to pulsate the diaphragm. In the present invention the cyclic venting and confinement is brought about by a pressure control valve which unseats at a high pressure (to vent the pressure chamber) and seats or resets at a significantly lower pressure (to close the pressure chamber). The pressure control valve must be more than a simple biased valve because such valves unseat or reset at a small pressure differential. Thus, a simple biased valve fails to promote expansion and contraction of the diaphragm and tends to oscillate, or "chatter."

The present invention provides an unexpectedly high differential in unseating and seating or resetting pressure. It provides a high pressure chamber differential pressure, in proportion to input pressure.

Summary of the invention

The invention is particularly suitable and advantageous for use where continuous circulation is necessary to maintain suspended or colloidal particles in suspension. It may also be advantageously used to supply paint to a sprayer because of the relatively low pressure developed in the pumped liquid. And, in general, it may be used for dis-

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pensing liquids ranging from paints, lacquers, coatings, lubricating fluids, and liquid chemicals.

The invention comprises a fluid pressure operated tubular diaphragm pump and includes a housing defining an inlet at one end and an outlet at the other, valve means disposed adjacent the inlet and adjacent the outlet, a tubular diaphragm axially disposed within the housing to provide a pressure chamber and a pumping chamber, the pumping chamber communicating with the inlet at one end and with the outlet at the other, means for cyclically introducing fluid pressure into the pressure chamber to thereby cause the diaphragm to alternately contract and expand, the means for cyclically introducing fluid pressure into the pressure chamber comprising conduit means defining a restricted fluid inlet leading to the pressure chamber, and a control valve assembly having an inlet passage communicating with the pumping chamber, an exhaust passage, a primary valve with a pressure responsive surface biased to closed position for controlling the flow of fluid through the exhaust passage, and a pilot valve with a pressure responsive surface smaller than the pressure responsive surface of the primary valve biased to closed position and exposed to the pressure in the inlet passage for controlling communication between the inlet passage and the larger pressure responsive surface of the primary valve, the pilot valve being adapted to open at a predetermined pressure in the inlet passage to cause subsequent opening of the primary valve, the pilot valve and primary valve remaining open until a substantial drop in the pressure in the pressure chamber has taken place.

The invention has among its objects:

To provide a tubular diaphragm pump having a pressure control valve which provides a high pressure differential, in proportion to input pressure, for alternately expanding and contracting the diaphragm;

To provide a tubular diaphragm pump having a pressure control valve which has a two-stage unseating and seating cycle of operation to thereby open and close at a high pressure differential;

To provide a tubular diaphragm pump having a pressure control valve which has an adjustable seating and unseating or resetting pressure to thereby control or adjust pressure chamber pressure and differential; and

To provide a tubular diaphragm pump having a pressure control valve which provides a pressure chamber differential pressure up to 80 and 85 percent of input pressure.

Description of the drawings

FIGURE 1 is a vertical sectional view of the pump which comprises the present invention. The pump is shown in service position in association with a container of liquid to be pumped;

FIGURE 2 is a sectional view of the cylindrical pump housing and tubular diaphragm taken on the line 2—2 of FIGURE 1;

FIGURE 3 is an axial sectional view of the pressure control valve assembly;

FIGURES 4, 5, 6 and 7 are diagrammatic vertical sectional views of the pump comprising the present invention. The figures represent the various stages in the cycle of operation of the invention.

FIGURE 4 shows the position of the tubular diaphragm, check valves and pressure control valve near the end of the charge cycle and immediately prior to the beginning of the discharge cycle, with the flexible valve disc of the pressure control valve fully seated.

FIGURE 5 shows the position of the above elements near the end of the discharge cycle with the flexible valve disc of the pressure control valve in its first stage of opening or unseating. The pilot valve portion of the pressure

control valve is open or unseated and the primary valve portion is seated.

FIGURE 6 shows the position of the elements near the end of the discharge cycle and immediately prior to the beginning of the charge cycle with the flexible valve disc of the pressure control valve in its second or fully unseated stage, thereby exhausting the pressure chamber. Both the pilot valve portion and the primary valve portion of the pressure control valve are unseated.

FIGURE 7 shows the position of the elements near the end of the charge cycle with the pressure control valve diaphragm in its first stage of closing or seating. The pilot valve portion of the pressure control valve is seated or closed while the primary valve portion is momentarily unseated prior to seating to thereby return to the position shown in FIGURE 4, to complete the cycle.

Description of the preferred embodiment

The illustrated embodiment of the invention may be generally understood with reference to FIGURE 1. Pump 10 is placed in service position in tank 11 to pump liquid 12 and includes intake 13, lower check valve 14, tubular diaphragm 15, upper check valve 16, surge tank 17 and outlet 18. Tubular diaphragm 15 is caused to pulsate by air pressure introduced at air inlet 19 into pressure chamber 20 which is cyclically exhausted, by the action of pressure control valve 21, through exhaust passage 22.

In operation, tubular diaphragm 15 is caused to contract by air pressure introduced into pressure chamber 20. As the pressure in chamber 20 increases, the diaphragm contracts and, when the limit of contraction is reached, pressure control valve 21 vents or exhausts the pressure in pressure chamber 20 through exhaust passage 22. The diaphragm then expands due to its resiliency. As the diaphragm 15 expands, liquid 12 is drawn into intake 13 and flows past lower check valve 14 and, into pumping chamber 23 of diaphragm 15. With the subsequent contraction of diaphragm 15, liquid 12 is forced upwardly from pumping chamber 23 past upper check valve 16, into surge tank 17, and through outlet 18.

With the foregoing general description of the invention the following detailed description may be readily understood.

Pump 10 includes a cylindrical pump housing 25 threaded to pump head section 26 at one end, and to foot section 27 at the other end. Head section 26 serves as a mounting means for upper check valve 16, surge tank 17, pump outlet nipple 28, air pressure inlet nipple 29 and air pressure outlet nipple 30. Head section 26 also serves to mount the upper end of tubular diaphragm 15. O-ring 31 is provided to insure an air-tight joint between head section 26 and diaphragm 15. Stepped bushing 32 wedges diaphragm 15 tightly against O-ring 31 to thereby hermetically mount the diaphragm to head section 26.

Foot section 27 similarly serves as a means for mounting the lower end of tubular diaphragm 15 and for that purpose stepped bushing 33, O-ring 34 and retaining ring 35 are provided.

Extension tubing 36 communicates with foot section 27 through adapter 37.

Upper check valve 16 is mounted to stepped bushing 32. Valve seat 38, mounted to stepped bushing 32, serves as a means for mounting valve cage 39. Valve member 40 is urged into engagement with valve seat 38 (closed position) by coil spring 41.

Lower check valve 14 is identical to upper check valve 16 and includes valve seat 42 seated in stepped bushing 33, valve cage 43, valve member 44, and coil spring 45.

Surge tank 17 is mounted to head section 26 at shoulder 46. Surge tank cover 47 threadably engages stem 48 and hermetically engages surge tank 17 due to the provision of O-ring 49.

The construction of pressure control valve 21 may be best understood with reference to FIGURES 1 and 3. Pressure control valve 21 includes an inlet section 50, 75

a cylindrical housing section 51, flexible valve disc 52, primary valve member 53, pilot valve member 54, and end section 55.

Inlet section 50, which is threaded to air pressure outlet nipple 30, has a central bore which defines an inlet passage 56 from the pressure chamber 20 to pilot valve seat 57 and primary valve seat 58. Pilot valve seat 57 and primary valve seat 58 are formed by concentric annular ridges. The circular area bounded by primary valve seat 58 is greater than the area bounded by pilot valve seat 57.

Cylindrical housing section 51 defines exhaust passage 22 and shoulder 59 and is threaded to end section 55 which defines vent 60 and shoulder 61.

Flexible valve disc 52 extends entirely across the inner wall of cylindrical housing section 51 and, accordingly, when seated against pilot valve seat 57 and primary valve seat 58, blocks inlet passage 56 from exhaust passage 22.

Primary valve member 53 is slideably mounted in end section 55 and serves to seat the peripheral portion of valve disc 52 on primary valve seat 58. For that purpose primary valve spring 62 acts against shoulder 61 of end section 55 to urge primary valve member 53 and the peripheral portion of valve disc 52 into engagement with primary valve seat 58. When valve disc 52 is so seated, inlet passage 56 is blocked from exhaust passage 22.

Pilot valve member 54 is slideably mounted within primary valve member 53 and engages flexible valve disc 52. Flexible valve disc collar section 64 serves to grip pilot valve member 54. Pilot valve spring 65 acts against end section 55 to urge pilot valve member 54 and flexible valve disc 52 into engagement with pilot valve seat 57.

The force with which primary valve spring 62 and pilot valve spring 65 acts upon primary valve member 53 and secondary valve member 63, respectively, may be varied, although the force of pilot valve spring 65 is always greater than the force of primary valve spring 62. To vary the force with which the two springs act, end section 55 may be adjusted, by means of its threaded engagement with cylindrical housing section 51, to increase or decrease the confined length of springs 62 and 65. Thus the pressure at which pressure control valve 21 vents inlet passage 56 through exhaust passage 22, may be varied, to thereby vary the pressure acting upon tubular diaphragm 15 in pressure chamber 20.

The design of pressure control valve 21 promotes an essential two-stage operation of flexible valve disc 52. In unseating, flexible valve disc 52 first unseats from pilot valve seat 57 and then unseats from primary valve seat 58 to vent inlet passage 56 through exhaust passage 22. In resetting or closing flexible valve disc 52 also operates in two stages. Pilot valve member 54 and spring 65 first act to seat flexible valve disc 52 on pilot valve seat 57 and subsequently primary valve member 53 and spring 62 act to seat flexible valve disc 52 on primary valve seat 58.

Exhaust passage 22 must be at least as large in cross-sectional area as inlet passage 56 but it should not be greater than about three times as large. Experimentation has also shown that the ratio of cross-sectional area of inlet passage 56 to restricted fluid inlet passage 70 must lie within the range of 3:1 to 30:1. In addition it has been noted that the volumetric ratio of pressure chamber 23 to restricted fluid inlet passage 70 should be about 40,000:1 for optimum results.

Tubular diaphragm 15 may be formed of nylon and its hardness may be 63 on the Shore "D" scale.

Operation

The operation of the present invention may be conveniently understood with reference to FIGURES 4-7.

In FIGURE 4 the pump components are shown at the beginning of the discharge cycle. Check valve 14 is open, diaphragm 15 expanded, check valve 16 is closed, and flexible valve disc 52 is seated on pilot valve seat 57 and primary valve seat 58 thereby blocking the exhaust passage 22 from air pressure inlet 19.

With exhaust passage 22 blocked, air pressure introduced at inlet 19 pressurizes the annular pressure chamber 20 between cylindrical diaphragm 15 and housing 25. The pressure causes diaphragm 15 to contract or collapse. As diaphragm 15 collapses, check valve 14 closes and check valve 16 opens. Liquid in pumping chamber 23 is forced upwardly around check valve 16 and discharges through pump outlet 18.

When diaphragm 15 reaches the limit of its contraction or collapse as shown in FIGURE 5, pressure in pressure chamber 20 increases and pressure against flexible valve disc 52 similarly increases. Eventually flexible valve disc 52 is unseated by air pressure from pilot valve seat 57, and assumes its first stage opening position as shown at FIGURE 5.

A pressure continues to increase (i.e., to approach the inlet pressure), flexible valve disc 52 unseats from primary valve seat 58, as shown in FIGURE 6, and exhaust passage 22 is placed in communication with restricted fluid inlet passage 70. The pressure in pumping chamber 20 is therefore vented and diaphragm 15 expands as air pressure exhausts to the atmosphere through exhaust passage 22.

As air pressure exhausts through exhaust passage 22 and as diaphragm 15 expands, check valve 16 closes and check valve 14 opens, as shown in FIGURE 7. The pump charges as liquid passes around check valve 14 and fills pumping chamber 23. With air pressure in pressure chamber 20 relieved through exhaust passage 22, flexible valve disc 52 first seats against secondary valve seat 57 as shown in FIGURE 7, and eventually becomes fully seated as shown at FIGURE 4. With the seating of flexible valve disc 52 on secondary valve seat 57, exhaust passage 22 is isolated from inlet passage 19. Pressure in pressure chamber 20, accordingly, builds up and the pump begins a subsequent cycle with the contraction of diaphragm 15.

The two-stage operation of flexible valve disc 52 is essential to provide a high pressure chamber differential in proportion to the constant input pressure. The pressure chamber differential is essential to promote full contraction and expansion of tubular diaphragm 15 and maximum liquid intake. Accordingly, as indicated previously, pressure control valve 21 must open to exhaust pressure chamber 20 at a given pressure and close to confine the chamber at a significantly lower pressure.

In a pressure input range of 35-120 p.s.i., the design of pressure control valve 21 provides an unexpectedly large annulus pressure differential when viewed with relation to the input pressure. More particularly, a pressure differential in the range of 80-85% of input pressure is achieved. Table I below shows the pressure differential at various input pressures in the range of 50-120 p.s.i. with the relief valve set for maximum differential (end section 55 set to provide maximum confinement of springs 62 and 65).

TABLE I.—ANNULUS DIFFERENTIAL PRESSURE, MAXIMUM SETTING

Input Press., p.s.i.	Pressure Differential, p.s.i.	Differential as a Percentage of Input Pressure, percent
50	40	80
65	53	81
80	68	85
95	80	84
110	92	83
120	102	85

While a pressure differential which represents a high percentage of input pressure is highly desirable, and while the high pressure differential provided by the present invention is a significant feature thereof, pressure control valve 21 may be adjusted or set to provide a lower pressure differential. With pressure control valve 21 set for minimum pressure differential (end section 55 set to provide minimum confinement of springs 62 and 65) the pressure differentials shown in Table II result.

TABLE II.—ANNULUS DIFFERENTIAL PRESSURE, MINIMUM SETTING

Input Press., p.s.i.	Pressure Differential, p.s.i.	Differential as a Percentage of Input Pressure, percent
50	11	22
65	12	18
80	16	20
95	26	27
110	40	36
120	50	41

Variations may be made in the illustrated embodiment without departing from the scope of the invention. For example, flexible valve disc 52 might be eliminated with its function taken over by two concentric piston-type valves. In addition the location of pumping chamber 23 could be interchanged with pressure chamber 20 without departing from the scope of the invention. Other changes might also be made without departing from the scope of the invention as defined by the following claims.

Having thus described the invention, what is claimed is:

1. A fluid-pressure operated, tubular-diaphragm pump comprising:

a housing defining an inlet at one end and an outlet at the other;

valve means disposed adjacent said inlet and adjacent said outlet;

a tubular diaphragm disposed within said housing to provide a pressure chamber and a pumping chamber, said pumping chamber communicating with said inlet at one end and with said outlet at the other, and means for cyclically introducing fluid pressure into said pressure chamber to thereby cause said diaphragm to alternately contract and expand, said means for cyclically introducing fluid pressure into said pressure chamber comprising:

conduit means defining a restricted fluid inlet passage leading to said pressure chamber, and

a control valve assembly having an inlet passage communicating with said pressure chamber, an exhaust passage, a primary valve with a pressure responsive surface biased to closed position for controlling the flow of fluid from said inlet passage through said exhaust passage, and a pilot valve with a pressure responsive surface smaller than the pressure responsive surface of said primary valve biased to closed position and exposed to the pressure in said inlet passage for controlling communication between said inlet passage and the larger pressure responsive surface of said primary valve, said pilot valve being adapted to open when exposed to a predetermined pressure in said inlet passage to cause subsequent opening of said primary valve, the pilot valve and primary valve remaining open until a substantial drop in the pressure in said pressure chamber has taken place.

2. The pump of claim 1 wherein the ratio of the cross-sectional area of said exhaust passage to the cross-sectional area of said inlet passage lies within the range of 1:1 to 3:1.

3. The pump of claim 1 wherein the ratio of the cross-sectional area of said inlet passage to the cross-sectional area of said restricted fluid inlet passage lies within the range of 3:1 to 30:1.

4. The pump of claim 1 in which a single flexible pressure-responsive member constitutes the pressure-responsive surface of both said primary and said pilot valves.

5. The pump of claim 4 wherein said pilot and primary valve have concentric annular seats cooperating with said flexible pressure-responsive member.

6. The pump of claim 2 wherein the ratio of the cross-sectional area of said inlet passage to the cross-sectional area of said restricted fluid inlet passage lies within the range of 3:1 to 30:1.

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7. The pump of claim 5 wherein the ratio of the cross-sectional area of said exhaust passage to the cross-sectional area of said inlet passage lies within the range of 1:1 to 3:1.

8. The pump of claim 7 wherein the ratio of the cross-sectional area of said inlet passage to the cross-sectional area of said restricted fluid inlet passage lies within the range of 3:1 to 30:1.

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