Nov. 20, 1962 R. N. KNIGHTS 3,064,582

RECIPROCATING PUMPS

Filed June 6, 1960 4 Sheets-Sheet 1

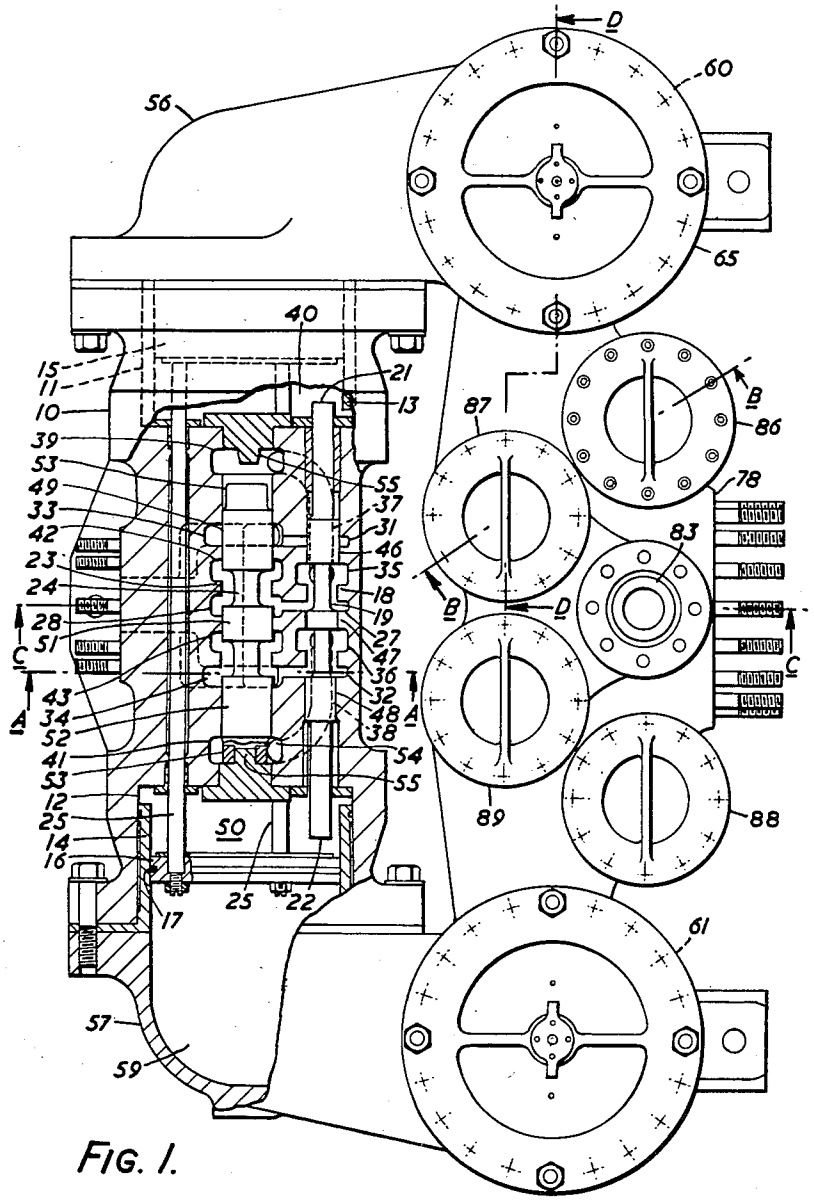


FIG. 1.

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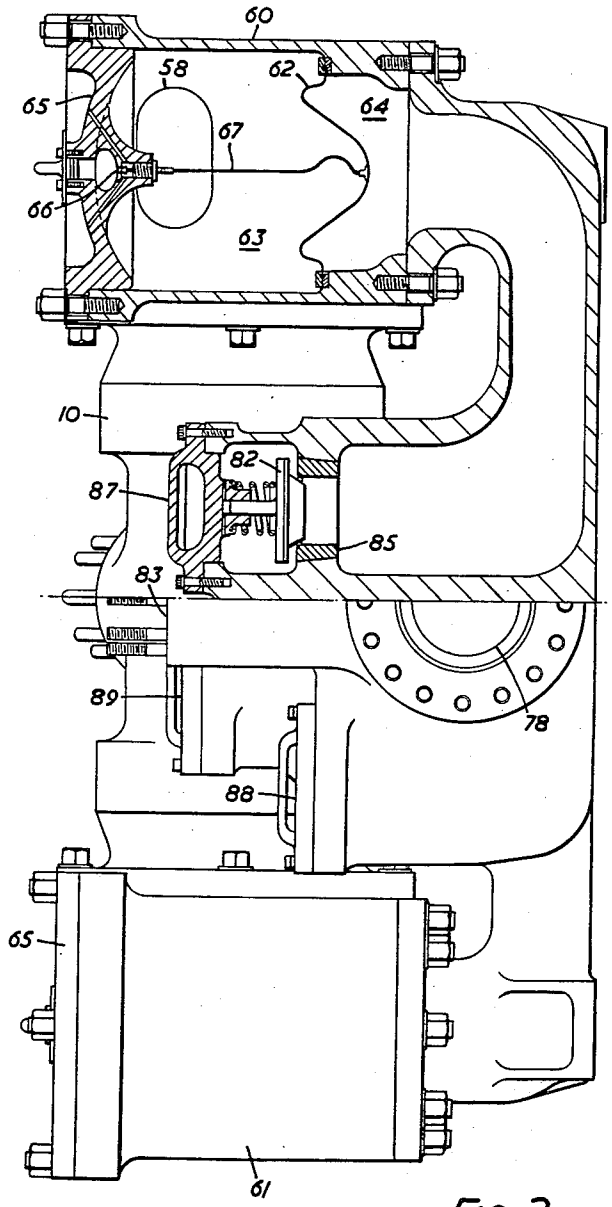


FIG. 2.

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Filed June 6, 1960 4 Sheets-Sheet 3

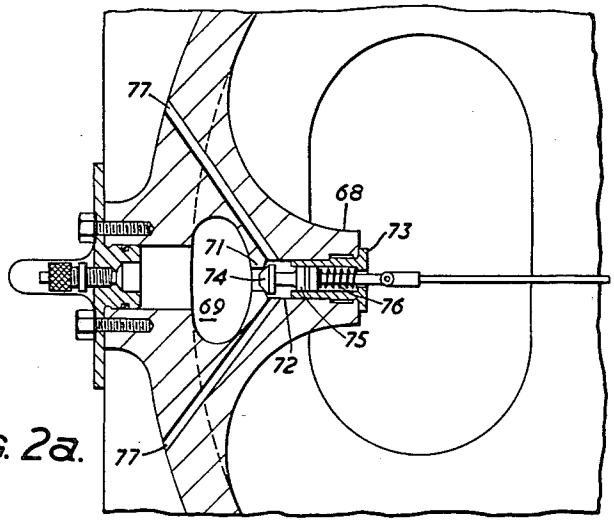


FIG. 2a.

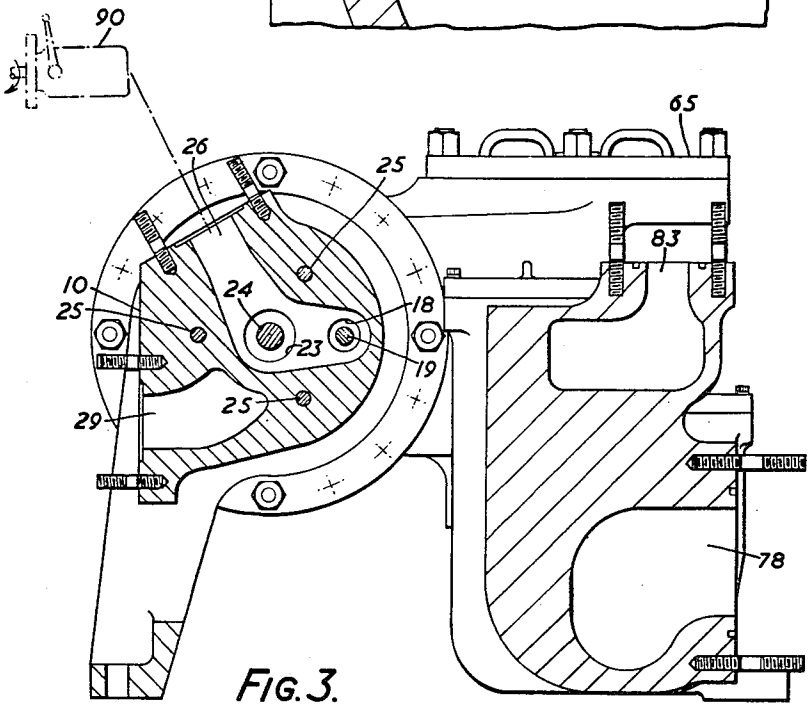


FIG. 3.

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Filed June 6, 1960 4 Sheets-Sheet 4

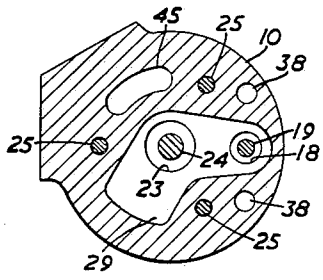


FIG. 4.

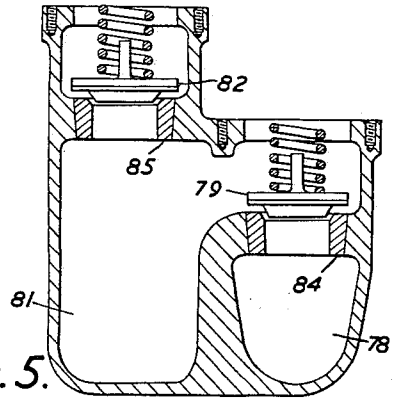


FIG. 5.

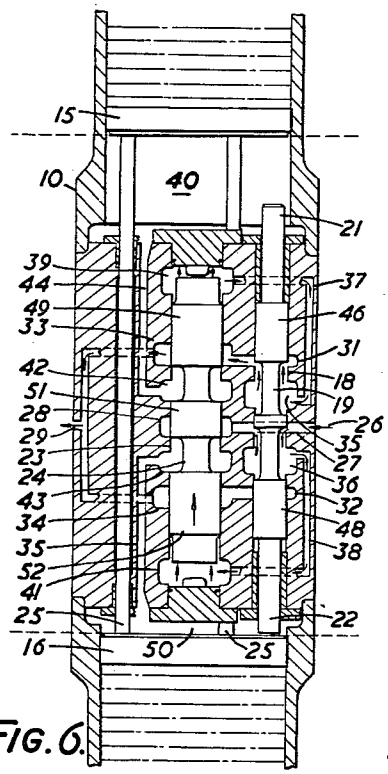


FIG. 6.

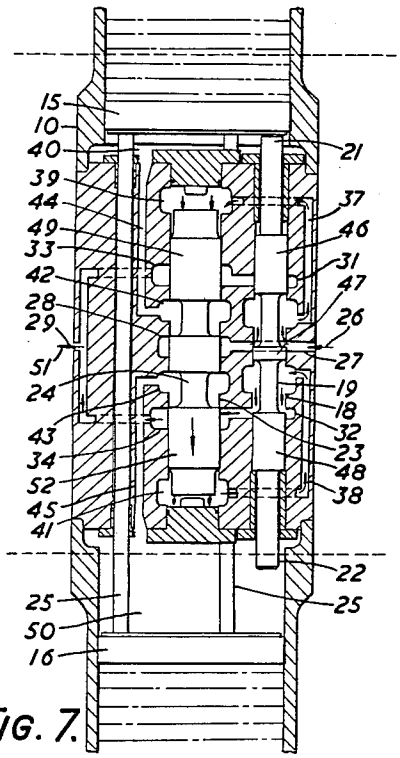


FIG. 7.

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3,064,582

# RECIPROCATING PUMPS

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3 Claims. (Cl. 103—44)

This invention relates to a reciprocating pump of the kind having a flexible diaphragm which separates the liquid to be pumped from the liquid which actuates the diaphragm reciprocally.

The object of the invention is to provide an improved construction of pump of this kind which is particularly suitable for pumping liquid suspensions of abrasive material, or for pumping corrosive liquids.

According to the invention a reciprocating pump for such liquids comprises a cylinder, a piston arranged to be reciprocated in the cylinder under the pressure of an actuating liquid, a flexible diaphragm separated from that face of the piston which is remote from the actuating liquid and which contains with said face a liquid-filled chamber of substantially fixed volume, and a pumping chamber on the other side of the flexible diaphragm arranged to receive the liquid to be pumped by the action of the piston through the liquid in the chamber of substantially fixed volume upon the flexible diaphragm.

According to a feature of the invention, a vent valve is provided responsive to flexure of the diaphragm on the pumping stroke beyond a given limit and opening at this limit to release liquid from the substantially fixed volume chamber if the diaphragm tends to flex beyond said limit.

In a preferred construction the piston is one of two pistons which are movable together and act alternately through substantially fixed volumes of liquid upon two flexible diaphragms.

The invention is illustrated in the accompanying drawings of which:

FIGURE 1 is a plan view of a pump suitable for pumping liquid mud with part of the working mechanism shown in section,

FIGURE 2 is a side elevation, the upper half of which is a section on the line D—D of FIGURE 1,

FIGURE 2*a* is an enlarged detail from FIGURE 2,

FIGURE 3 is a central section on the line C—C of FIGURE 1,

FIGURE 4 is a section on the line A—A of FIGURE 1,

FIGURE 5 is a section on the line B—B of FIGURE 1, and

FIGURES 6 and 7 are sectional diagrams of the pump at different stages of operation.

The pump comprises a central valve housing **10** formed at opposite ends with co-axial bores **11** and **12** in which are fitted replaceable cylinder liners **13** and **14**. Pistons **15** and **16** provided with sealing rings **17** are slidably mounted in the respective cylinders **13** and **14**, and connected for movement in unison by three equally spaced connecting rods **25**, which pass slidably through and are suitably sealed with respect to the valve housing **10**. The pistons **15** and **16** are arranged to be reciprocated hydraulically under the control of a pilot valve and a main valve in the housing **10**. The pilot valve comprises a cylindrical bore **18** parallel to the axis of the housing **10** and a valve spool **19** slidable therein. The spool **19** has tail rods **21** and **22** at opposite ends which are engageable by the pistons **15** and **16** respectively towards the ends of their reciprocating strokes so as to shift the valve spool **19** from one end position to another. The pilot valve controls a main valve comprising a cylindrical bore **23** on the central axis of the housing **10** and a valve spool **24** slidable therein.



A liquid pressure inlet **26** in the housing **10**, see FIGURE 3, leads to pressure grooves **27** and **28** in the bores **18** and **23** of the pilot and main valves respectively, and a low pressure outlet **29** connects with axially separated grooves **31**, **32** and **33**, **34** in the respective bores **18** and **23**. Axially separated grooves **35** and **36** in the bore **18** lead through passages **37** and **38** to grooves **39** and **41** at the upper and lower ends of the main valve bore **23**. Axially separated grooves **42** and **43** in the main valve bore **23** lead through passages **44** and **45** in the housing **10** to chambers **40** and **50** enclosed between the respective pistons **15** and **16** and the housing **10**. These passages **44** and **45** are readily seen in the diagrams of FIGURES 6 and 7, and the passage **45** is shown in the section of FIGURE 4. The pilot valve spool **19** is formed with three axially separated lands **46**, **47** and **48**, and the main valve spool **24** is formed with three axially separated lands **49**, **51** and **52**. The main valve spool **24** has counter-bored ends **53** with small cross drillings **54**. Each end is engageable over a fitting spigot **55** whereby the terminal movement of the main spool **24** is cushioned by the discharge of hydraulic liquid through the cross drilling **54**.

The operation of the mechanism as thus far described is as follows. The pilot valve spool **19** is hydraulically balanced and fits the bore **18** sufficiently tightly to stay in one end position or the other. As shown in FIGURE 1, the pressure groove **27** is open between the lands **46** and **47** to the groove **35** so that pressure has access through the passage **37** to the groove **39** at one end of the main valve spool **24**. The spool **24** is thus maintained in one end position whereby pressure liquid from the groove **28** has access through the groove **42** and passage **44** to the chamber **40**, while the opposite chamber **50** opens through the passage **45** to the groove **43** and between the lands **51** and **52** to the low pressure groove **34**. The piston assembly **15**, **16**, **25** therefore moves upwardly with respect to FIGURE 1 until near the end of its stroke the piston **16** engages the tail rod **22** and shifts the pilot valve spool **19** over to the position in the diagram of FIGURE 6.

Pressure liquid from the groove **27** now passes between the lands **47** and **48** to the groove **36**, and thence through the passage **38** to the groove **41** at one end of the main valve spool **24**. Simultaneously the groove **39** at the other end of the main valve spool opens through the passage **37** and groove **35**, between lands **46** and **47** to the low pressure groove **31** which is in communication with the low pressure outlet **29**. The main valve spool **24** then moves upwardly with respect to FIGURE 6 where the lands **51** and **52** are about to connect the pressure groove **28** with the groove **43**, and the lands **49** and **51** are about to connect the low pressure groove **33** with the groove **42**. The chamber **50** is then connected to high pressure at the inlet **26** while the chamber **40** is connected to low pressure at the outlet **29** whereupon the piston assembly **15**, **16**, **25** moves in the reverse direction. At the end of its stroke the piston **15** shifts the valve spool **19** over to the position shown in FIGURE 7, thus causing the main valve spool **24** to move over whereby the pressure and return connections to the chambers **40** and **50** are again reversed. Thus the pilot valve and main valve cause the pistons **15**, **16** to reciprocate back and forth automatically under liquid pressure at the inlet **26**.

The construction by which the reciprocating pistons **15** and **16** are arranged to pump liquid suspensions of solids such as mud will now be dsecribed. End housings **56** and **57** attached to the central valve housing **10**

have cavities 58 and 59 which open into cylinders 60 and 61 forming part of the respective housings 56 and 57. As the construction is a symmetrical one, only the one half shown in section in FIGURE 2 will be described. The cylinder 60 is divided by a thin flexible diaphragm 62 into a hydraulic liquid chamber 63 and a pumping chamber 64.

The cylinder 60 is closed at one end by a cap 65 having a centrally arranged vent valve 66 which is openable by a tension element provided by a cord 67 attached to the centre of the diaphragm 62, this cord 67 acting in tension on the valve 66 when the diaphragm 62 is flexed at a permissible maximum volume of the hydraulic liquid chamber 63. The valve 66 shown on a larger scale in FIGURE 2*a* comprises an inwardly directed boss 68 having behind it an opening 69 from the chamber 63. The opening 69 leads to a valve seat 71, and a bore 72 in which a cylindrical sleeve 73 is fixed, while a movable valve member comprises a valve head 74 engageable with the seat 71 and a piston 75 slidable in the sleeve 73. The diameter of the piston 75 is equal to the diameter of the seat 71 whereby the movable member is balanced hydraulically, but a spring 76 is interposed between the sleeve 73 and the piston 75 to close the valve. Vent holes 77 in the boss 68 lead from the bore 72 to the exterior of the cap 65.

An inlet 78 for liquid mud at the centre of the housing 10 opens through a non-return inlet valve 79 into a passage 81 which leads to the mud chamber 64, see FIGURE 5. The passage 81 also opens through a non-return outlet valve 82 to an outlet 83 in the housing 10. The valves 79 and 82 are spring-loaded on to replaceable seating rings 84 and 85, and the complete valve assemblies are accessible through covers 86 and 87 respectively. Covers 88 and 89 enclose similar non-return valves leading to and from a mud chamber in the cylinder 61. The inlet 78 and outlet 83 are common to both mud chambers wherein the pumping takes place alternately upon reciprocation of the pistons 15 and 16.

The pumping of mud in the chamber 64 takes place under the action of a substantially constant volume of hydraulic liquid in a chamber formed between the piston 15 and the diaphragm 62. The volume is such that the diaphragm 62 will flex equally on opposite sides of its midway position, and its maximum possible volumetric displacement is substantially greater than full volumetric displacement of the pistons 15 and 16 whereby the diaphragm 62 will not become distended with consequent risk of rupture at the extreme limits of its stroke.

The pistons 15 and 16 provide by means of the packing rings 17 a sliding seal against the cylinder liners 14, so that if after prolonged use there tends to be a leakage of hydraulic liquid from the chambers 46 and 47 across the rings 17, the volume of liquid between the pistons 15 and 16, and the diaphragm 62 will increase. A feature of the invention is that this volume is prevented from increasing beyond a prescribed amount in order to prevent the risk of rupturing the diaphragms at the end of their pumping strokes. This safeguard is provided by the cord 67 which is pulled tight by the diaphragm 64 before the latter reaches the safe limit of flexure at the end of its pumping stroke. The cord 67 then pulls the valve head 74 off its seat 71 and allows a quantity of excess hydraulic liquid to be vented to the outside of the cap 65 whereby a safe volume of liquid is maintained. The rate at which liquid accumulates in either cap 65 indicates whether the sealing rings 17 and cylinder liners 14 require inspection and replacement.

Each diaphragm 62 is subject to negligible pressure differences across it so it can be thin, thereby decreasing the internal stresses in the material upon flexure and increasing its working life. If for any reason the diaphragm ruptures, the reciprocating mechanism in the housing 10 is substantially safeguarded from penetration of the liquid mud, which may be abrasive, by the piston



15 or 16 as the case may be until the rupture is discovered in the course of routine inspection.

The actuating liquid may be supplied to the high pressure inlet 26 by a variable delivery pump shown diagrammatically at 90 in FIGURE 3. If the pump 90 is driven at constant power input the delivery can be varied to give a large flow at a relatively low pressure or a small flow at a relatively high pressure, and the output of the reciprocating pump will vary accordingly. This is of particular advantage when the reciprocating pump is used to supply mud to an earth boring rig because the variation of delivery described is required as the drilling proceeds to greater depths.

The ratio of the pressure of the actuating liquid on one side of each piston 15 or 16 to the liquid pressure on the other side is dependent upon the ratio of the respective areas. The latter ratio may be selected in designing the pump by means of the total effective area of the tie rods 25. Alternatively, a stepped piston may be provided.

I claim as my invention:

1. A reciprocating pump for liquids comprising two co-axial cylinders, a piston assembly including two pistons mounted for reciprocal movement together in the respective cylinders, a reversing valve including an inlet adapted for connection with a source of actuating liquid, two passages each of which is connected with one of said cylinders, and valve-operating means co-acting with the piston assembly upon reciprocal movement of the latter to reverse the connection of said inlet with the said two passages whereby the piston assembly is reciprocable automatically under the pressure of the source of actuating liquid, a flexible diaphragm mounted in spaced relation from that face of each piston which is remote from the actuating liquid, a liquid-filled chamber disposed between each piston and the flexible diaphragm associated therewith, the liquid therein forming a transmission medium operative to flex the diaphragm reciprocally in accordance with the reciprocatory motion of said piston, a vent valve connected to each liquid-filled chamber, an operating element for each vent valve disposed for displacement by the diaphragm upon flexure of said diaphragm beyond a given limit caused by the pressure stroke of the associated piston, said element being operative at this limit to open the vent valve and release any excess of liquid in said chamber whereby the diaphragm is restored to said limit, and for each diaphragm a pumping chamber disposed on the other side of the diaphragm from said liquid-filled chamber, said reversing valve comprising a main valve having a valve spool operative in its end positions to connect the inlet for actuating liquid respectively with the passage connected to one cylinder or the passage connected to the other cylinder, pressure responsive means operative upon the valve spool, and a pilot valve having a valve spool operative in its end positions to connect the inlet for actuating liquid with said pressure responsive means so as to displace the main valve spool to one end position or the other, said pilot valve spool being adapted for co-operative two-way engagement with the piston assembly so as to be displaceable into one end position or the other upon completion of each reciprocating stroke of the piston assembly.

2. A reciprocating pump for liquids comprising two co-axial cylinders, a piston assembly including two pistons mounted for reciprocal movement together in the respective cylinders, a reversing valve including an inlet adapted for connection with a source of actuating liquid, two passages each of which is connected with one of said cylinders, and valve-operating means co-acting with the piston assembly upon reciprocal movement of the latter to reverse the connection of said inlet with the said two passages whereby the piston assembly is reciprocable automatically under the pressure of the source of actuating liquid, a flexible diaphragm mounted in spaced relation from that face of each piston which is remote from the actuating liquid, a liquid-filled chamber disposed between

each piston and the flexible diaphragm associated therewith, the liquid therein forming a transmission medium operative to flex the diaphragm reciprocally in accordance with the reciprocatory motion of said piston, a vent valve connected to each liquid-filled chamber, an operating element for each vent valve disposed for displacement by the diaphragm upon flexure of said diaphragm beyond a given limit caused by the pressure stroke of the associated piston, said element being operative at this limit to open the vent valve and release any excess of liquid in said chamber whereby the diaphragm is restored to said limit, and for each diaphragm a pumping chamber disposed on the other side of the diaphragm from said liquid-filled chamber, the said reversing valve being mounted in a housing disposed between the two co-axial cylinders, the two pistons which are mounted in said cylinders being connected together by tie rods which pass through the housing.

3. A reciprocating pump for liquids comprising two fixed cylinders each having an inward and an outward end, a piston assembly including two pistons mounted in the respective cylinders between the inward and outward ends thereof, and connecting means extending from one piston through the inward ends of the two cylinders to the other piston to co-ordinate reciprocal inward and outward movements of one piston in its cylinder with reciprocal outward and inward movements respectively of the other piston in its cylinder, said connecting means having opposite end portions within the cylinders of uniform finite cross-sectional area whereby the effective area of the inner end of each piston is less than the effective area of the outer end, two passages each of which is connected with one of said cylinders at a position behind the inner end of the piston mounted therein, a reversing valve including an inlet for connection with a source of actuating liquid under pressure and arranged to connect said inlet to one or the other of said passages, and valve-operating means arranged for operation by the piston assembly upon reciprocal movements of the pistons in their cylinders to connect said inlet with one such passage, and to cyclically reverse the connection of said inlet with the said two passages, whereby the piston is reciprocable automatically under the pressure of the liquid source applied to the inner ends of the pistons in turn, a diaphragm chamber disposed at the outward end of each cylinder including a flexible diaphragm dividing said chamber into two parts, one of said parts adjoining the cylinder, said one part, between the outer end of the piston and the diaphragm, being adapted to contain a substantially constant trapped volume of liquid which constitutes a pressure transmitting medium actuated by reciprocation of the piston to flex the diaphragm alternately outwardly from the cylinder and inwardly, a vent valve communicating with the part of each diaphragm chamber that contains the liquid pressure transmitting medium, said vent valve comprising an opening from said chamber communicating with low pressure, a movable valve element normally closing said opening, and a valve-operating element arranged for operation in response to outward flexure of the diaphragm beyond a given limit to displace the movable valve-element from the opening for releasing liquid transmitting medium in excess of the substantially constant trapped volume, an inlet valve communicating with the other part of said chamber and adapted for connection with the source of liquid to be pumped and an outlet valve for pumped liquid also communicating with such other part of the chamber, and a common outlet for pumped liquid connected to the outlet valves of both diaphragm chambers.

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