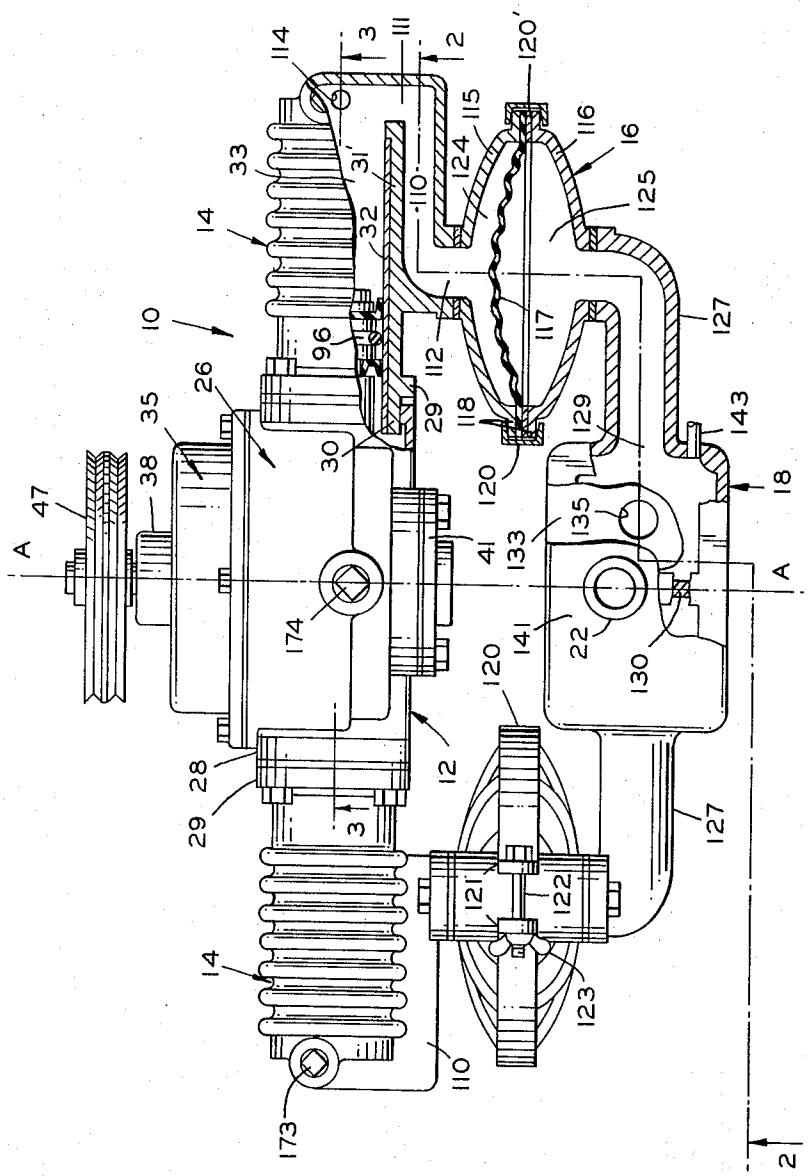
Feb. 21, 1967 W. H. GROWALL ET AL 3,304,870

PLUNGER DIAPHRAGM PUMP

Filed Feb. 15, 1965 5 Sheets-Sheet 1

FIG. 1



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PLUNGER DIAPHRAGM PUMP

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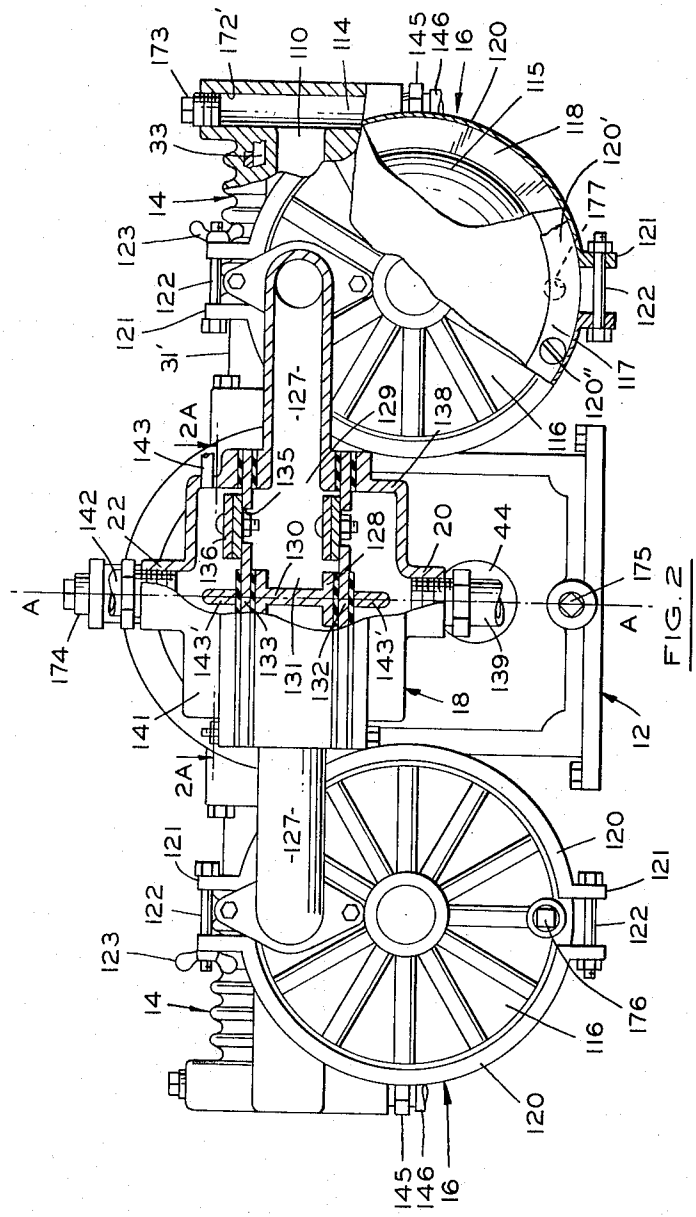

FIG. 2

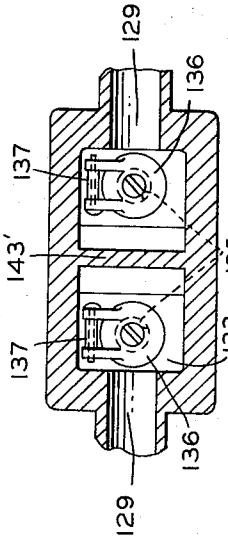

FIG. 2A

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PLUNGER DIAPHRAGM PUMP

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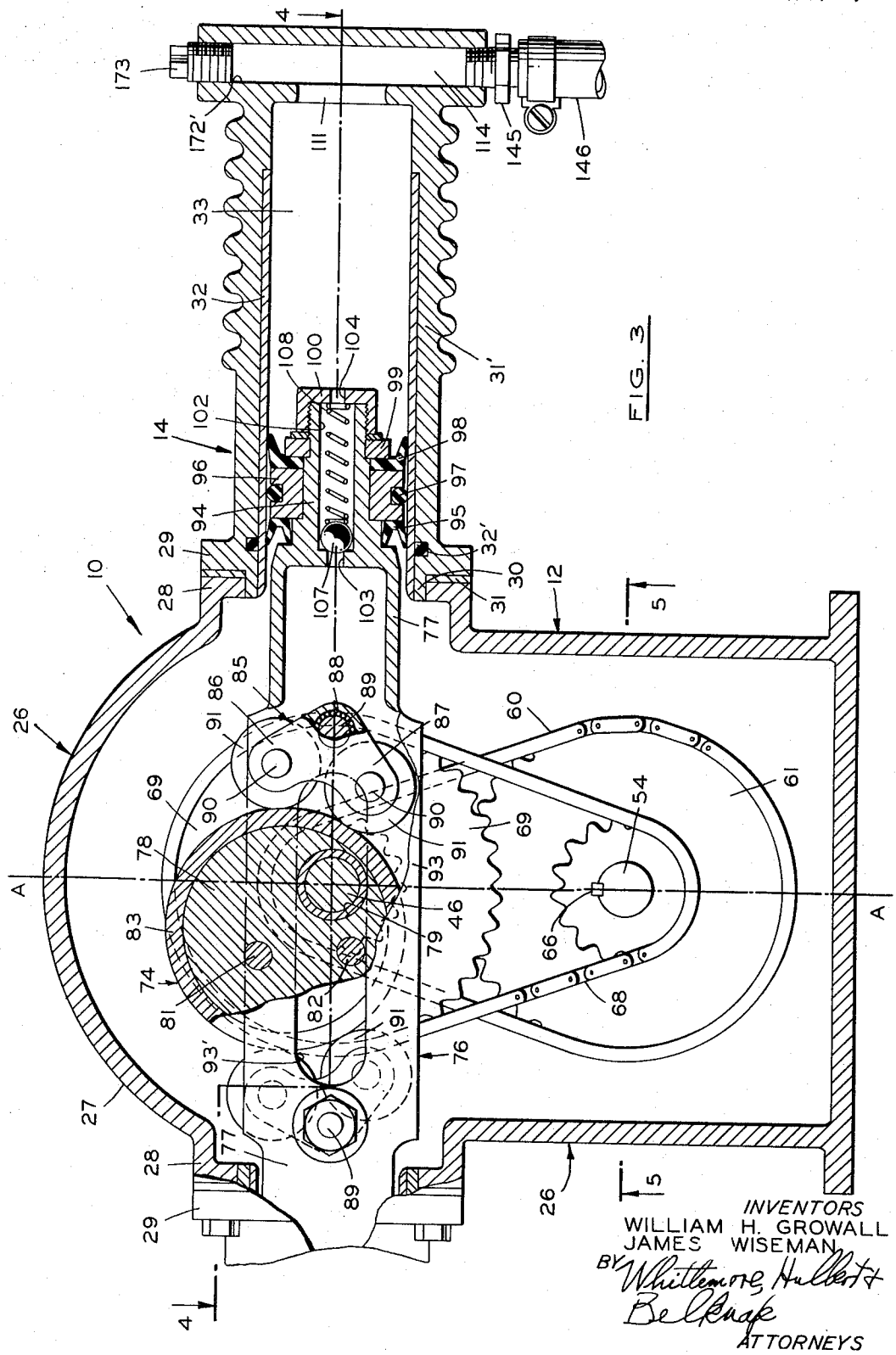

FIG. 3

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PLUNGER DIAPHRAGM PUMP

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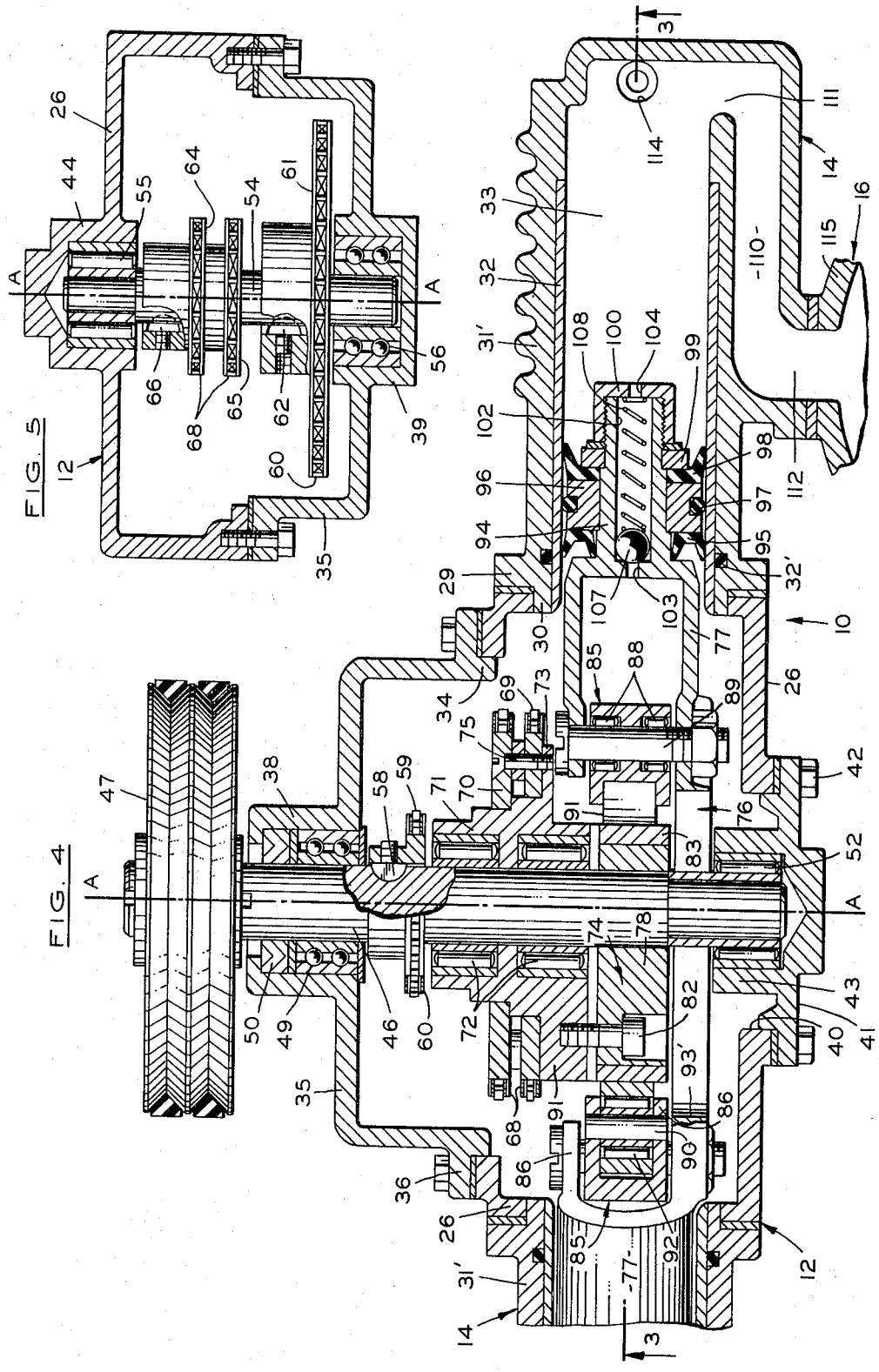

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PLUNGER DIAPHRAGM PUMP

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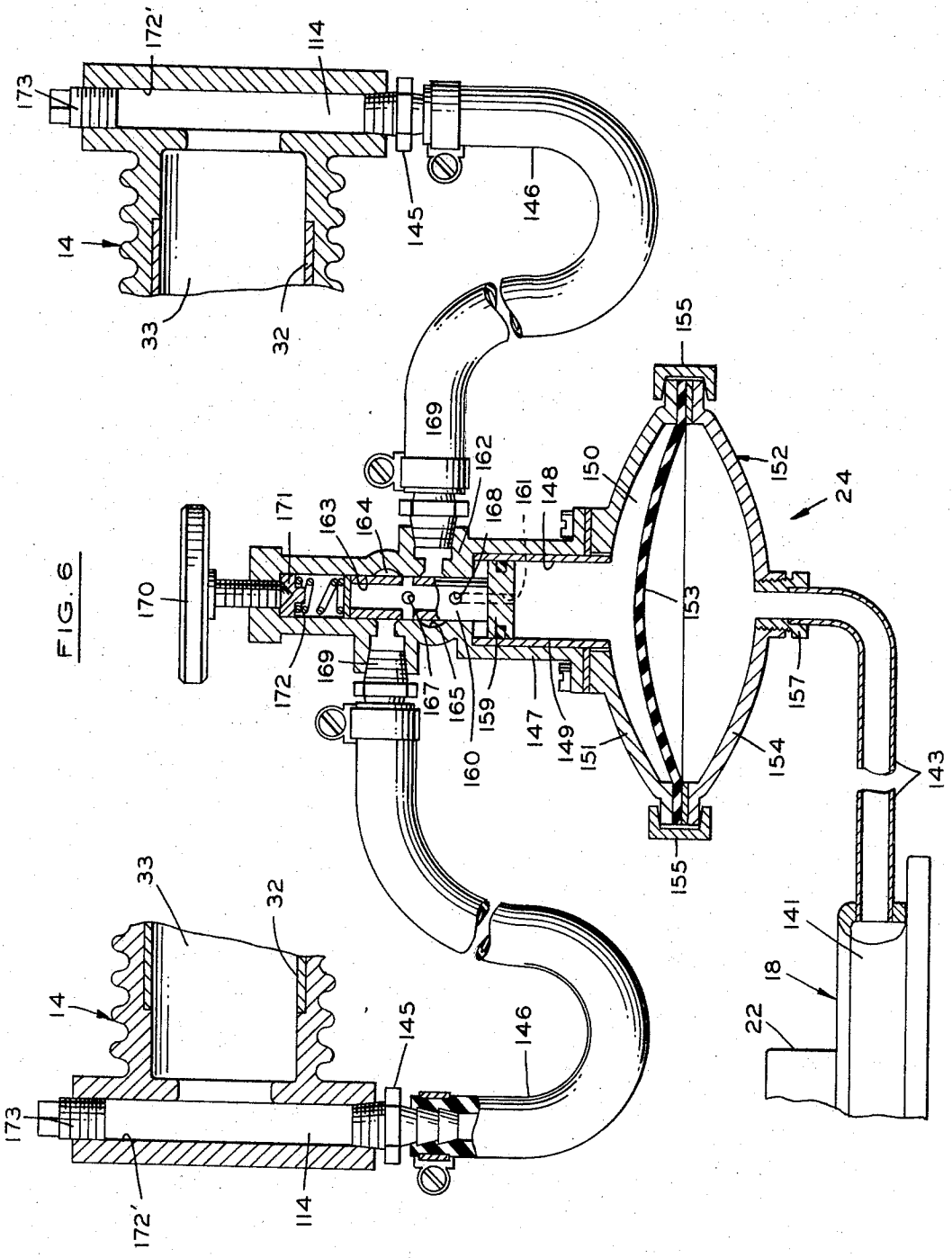

FIG. 6

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PLUNGER DIAPHRAGM PUMP

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20 Claims. (Cl. 103—44)

The present invention relates to an improved combination of plunger pump and diaphragm pump units which may be constructed with little or no increase in size, weight or cost as compared with either a conventional plunger or diaphragm pump of similar capacity. Yet the improved pump avoids many known drawbacks of the latter and has many advantages of its own over either type, or known combinations thereof.

Thus, a customarily constructed piston or plunger pump has limiting endurance characteristics which make it unsuitable for many applications, such as handling of abrasive fluids or materials with an adhesive content. Also in installations handling extremely high pressure it becomes a very difficult matter to provide an adequate lubricant for the cylinder walls and piston rings, due to the fact that many of the liquids pumped contain abrasive materials and no lubricant qualities whatsoever. In many cases an oil bath system of lubrication is not practical, as when an edible material is being pumped, because of leaking by piston rings of contaminating oil; in addition to the fact that in some installations a liquid being pumped, and which may leak at elevated pressure past the piston, may be highly detrimental to the latter's guiding mechanism, wrist pins, connecting rod bearings, main bearings, etc.

In reference to the conventional diaphragm pump, it usually has a driver connecting rod attached to the center of a diaphragm, and power is transmitted to this point only. Therefore, the area surrounding the center is dependent upon its own tensile strength to avoid damage or destruction when a load is placed against it, either on an intake or discharge stroke. Since the strength of the diaphragm is limited, especially after extended use, its pressure handling capability must remain low.

In general, it is an object of the invention to provide an improved plunger-diaphragm pump which avoids the above-mentioned drawbacks of known plunger or diaphragm pumps, as well as combined plunger and diaphragm pumps of which we are aware, and which is therefore capable of pumping efficiently, and in large or small volume, a vast number of different materials ranging from water through paints and other surface coating materials, molding materials, disinfecting and cleaning liquids, adhesives, and the like. Water is hereinafter mentioned simply as being typical.

In accordance with the invention, and as distinguished from known piston pumps, the improved pump has all of its moving parts submerged in oil, which in turn is sealed safely and securely from any liquid material being pumped. Such component parts, save those in direct contact with the liquid being pumped, may be constructed from the low cost materials, since there is no problem of rust or corrosive action upon bearings, driving mechanisms, etc. Moving parts, as well as associated stationary components, are assured of long life by an efficient lubrication system.

Moreover certain plunger sealing members of the improved pump are located between two substantial bodies

of clean oil. Hence, not only are practically all moving parts lubricated in a bath of oil, but no air is present to seep by the plunger members and, accordingly, cause air pocket accumulation, such as would prevent the build up of extremely high pressures which the improved pump is designated to produce.

In comparison with existing diaphragm pumps, the improved combination pump applies a plunger-pressurized body of oil over each square inch of its diaphragm surface, thus transmitting such pressure against an equally distributed load on the other side of the diaphragm surface. Due to this principle, the force and load are equalized at all required pumping conditions, and the diaphragm is not subjected to damaging or destructive stress, hence may exert pumping forces incapable of attainment in a rod-operated diaphragm pump.

Further in accordance with the general concept of the invention, the improved pump is constructed of component, fixed casing and housing parts which are assembled to one another in a manner to enable the same to be readily and quickly dismantled for inspection or servicing, and equally readily reassembled, these housing and casing components also having improved means for draining liquid therefrom.

More particularly, it is an object of the invention to provide a pump having a plunger actuating cam unit immersed in oil in a combined cam and transmission casing, along with a speed-reducing and torque-increasing transmission unit connecting the cam unit to an external power source.

Moreover, the invention also provides an improved type of plunger unit driven in reciprocation by the power unit including a pair of opposite plunger heads rigidly coupled together for vacuum and pressure strokes in a pair of oil cylinders on opposite sides of the cam-transmission casing. Thus, the undesirable effects of side thrust, as in a connecting rod-operated plunger, are avoided, the cam unit transmitting a strictly linear line of reciprocating action to the plunger unit and its heads.

Still more specifically, the invention provides an improved type of dual roller cam follower for coaction with the cam unit, including a pair of rollers having means cradling the same on a pivotal axis on each of the plunger heads, these rollers smoothly and continuously following the cam contour as the latter is driven at reduced speed by the transmission in a way to eliminate noise.

In another specific aspect, the pump of the invention has valved balancing provisions built into each of its oil pressurizing plungers to permit a compensating flow of oil from one side of the latter to the other, when the plunger and cylinder in question are in a vacuum cycle.

For a different, though related purpose, the pump of the invention preferably incorporates an oil pressure equalizing or balancing unit in the event of an objectionably high build up of oil pressure on either side of the system, bypassing abnormal high pressure to the lower pressure side.

The foregoing as well as other objects will become more apparent as this description proceeds, especially when considered in connection with the accompanying drawings illustrating the invention, wherein:

FIG. 1 is a top plan of the improved dual acting plunger-diaphragm pump, being in part broken away and in horizontal section in a plane through the cylinder axis of the pump, as well as in further section parallel to that plane and closer toward the viewer;

FIG. 2 is a side elevational view, as from the bottom of FIG. 1, being partially broken away and sectioned vertically along a line approximating the broken line 2—2 of FIG. 1;

FIG. 2A is a plan view, as from the line 2A—2A of FIG. 2, showing a valve mounting plate of a pumped liquid distributing valve unit of the pump;

FIG. 3 is a view partially broken away and in vertical section along line 3—3 of FIG. 1 through the cam and transmission casing of the pump, this view being further sectioned on other vertical and parallel planes proceeding in the direction away from the viewer;

FIG. 4 is, in the main, a top plan view, being broken away and horizontally sectioned along line 4—4 of FIG. 2;

FIG. 5 is a view partially broken away and in horizontal section on line 5—5 of FIGS. 2 and 3; and

FIG. 6 is a side elevational view, partially broken away and in vertical section, corresponding for example to the right-hand side of FIG. 3, showing an improved oil pressure equalizing or balancing device of the pump.

The improved dual-type plunger and diaphragm pump of the invention is generally designated by the reference numeral **10**, and it is symmetric as to its operating and control instrumentalities about a central vertical plane, designated A—A in FIGS. 1 through 5 of the drawings. Accordingly, the following description of such components, as expressed in regard to one-half of the structure, for example, its right or left hand side, also applies to the identical other half.

Pump **10**, in general reference to its basic components, comprises an oil-filled main casing, generally designated **12**, containing certain power transmission and drive cam provisions to be described, and the casing has fitted to opposite ends thereof a pair of pump cylinder and manifold housings **14**, which housings communicate with diaphragm pump units **16**, all as illustrated in FIGS. 1 through 5 of the drawings.

The diaphragm units **16** are in turn connected to a central flow distributor valve chest **18**, as best shown in FIGS. 1 and 2; and the chest **18** has intake and discharge fittings **20**, **22**, respectively, adapted to be connected to a source of liquid to be pumped and to a disposal point. Valve chest **18** is also connected with an oil pressure balancing or equalizing unit **24** (FIG. 6) for a protective purpose to be described; and certain plunger components (also to be described) within the housings **14** are designed for a related function.

The power transmission and drive cam casing **12** is in the form of a rugged body casting providing an upright base or body **26** adapted to rest upon a suitable horizontal support. The casing **12** has an arcuate top portion **27** to accommodate certain sprocket means therein, and is also formed to provide opposed laterally opening bosses **28**. Each cylinder and manifold housing **14** has an annular radial flange **29** presenting a projecting rim formation **30** which pilots accurately in a casing boss **28**, with a sealing gasket **31** interposed. Each housing **14** also has an elongated, hollow cylinder portion **31'** fitted with an elongated steel liner **32**, and cylinder portion **31'** is equipped within the flange **29** with an O-ring **32'** surrounding and externally sealing the liner, which defines an oil cylinder space **33** of each of the cylinder and manifold housings **14**.

The opposed cylinder and manifold housings **14** are accurately mounted by their integral rims **30** in the apertured bosses **28** of the main casing **12**, with the cylinders **33** thereof in accurate axial alignment with one another, and with the space between the housing bore and liner **32** well sealed by the O-ring **32'**, as shown in FIG. 4.

The casing **12** has at the rear thereof a large size opening **34**, into which is piloted a rim of a recessed rear closure plate **35**, and an outwardly projecting marginal flange **36** of this plate is bolted to the rear of casing body **26** about opening **34**. Thus certain bearing provisions of the cover or closing plate **35** are properly centered in relation to the casing body or base **26**. Closure member **35** is provided with an outwardly projecting and opening tubular boss **38** (FIGS. 1 and 4), and directly beneath the boss **38** the plate **35** is provided, as shown in FIG. 5, with a second outwardly projecting boss **39** which is a closed or blind one, as distinguished from the axially outwardly exposed boss **38**.

Furthermore, the forward upright wall of casing base **26** is provided, opposite the boss **38** of rear closure plate **35**, with an opening **40** in the wall in question, this opening being covered by a closure plate **41**, which is secured to that wall, with a gasket interposed, by a series of bolts **42**. The closure **41** has an inwardly projecting tubular boss **43**. Directly beneath the opening **40** and plate **41** the forward wall of base **26** of casing **12** is provided (FIG. 5) with an internally recessed, externally closed boss **44**; and the lower casing and plate bosses **44**, **39**, respectively, are in true axial alignment with one another, as are also the respective bosses **43**, **48** thereabove.

As shown in FIG. 4, the main drive shaft for the pump **10** is designated by the reference numeral **46**. It extends outwardly through the boss **38** of casing closure plate **35**, where it carries a double pulley **47**, which is a power-input member for the pump **10** driven by an appropriate motor, engine or other prime mover unit. Inwardly of this zone the main shaft **46** has an anti-friction journal in boss **38** by means of a rugged double ball bearing **49**, the shaft being oil-tight sealed by an appropriate packing **50**. The opposite end of shaft **46** is similarly journaled in the boss **42** of closure plate **41** by means of a heavy duty, slip fit roller bearing **52**, the inner race of which is press fitted onto a reduced diameter end of the shaft.

Referring to FIG. 5, a secondary idler or countershaft of the pump **10**, which parallels shaft **46**, is generally designated **54**, being located beneath and in a vertical plane including the axis of shaft **46**. Countershaft **54** is journaled at one end in a roller bearing **55** in the lower boss **44** of the body **26** of casing **12**; and the opposite end of shaft **54** is similarly journaled by a double ball bearing **56** in the opposite boss **39** of closure plate **35**. Thus, the shafts **46**, **54** are supported for rotation in casing **12** by means of efficient heavy duty bearing provisions; and it is evident that upon removal of pulley **47** from shaft **46** and closure plate **35** from main casing body **26**, the entire bearing structure, also various drive provisions to be described, is accessible for inspection and servicing. Initial assembly is also facilitated.

Directly within the recessed closure plate **35**, main drive shaft **46** (as shown in FIG. 4) has fixedly secured thereon, as by a key **58**, a relatively small diameter chain sprocket **59**, about which a primary power input chain **60** (FIG. 3) is trained downwardly around a larger diameter sprocket **61** fast on countershaft **54** directly therebeneath, as by a key **62** on the hub of the sprocket (FIG. 5). A pair of secondary driving sprockets **64**, **65** of like diameter, considerably smaller than that of the driven sprocket **61**, are also secured by key means **66** to countershaft **54**, either as individual sprocket elements or as a unitary, double sprocket structure. A pair of secondary driving chains **68** are trained upwardly, as shown in FIG. 3, about the respective small diameter sprockets **64**, **65**, and around a pair of secondary driven sprocket rings **69**, **70**, respectively, which are of larger diameter than and disposed directly above the sprockets **64**, **65**.

Sprocket rings **69**, **70** are mounted by a tubular sprocket hub **71**, which is rotatably journaled on main drive shaft **46** through the agency of sets of heavy duty, free floating roller bearings **72**, and hub **71** is provided with an integral radially extending circular flange **73**. Sprocket rings **69**, **70** are telescoped over stepped cylindrical formations of hub **71**; and an annular series of screws or bolts **75**, with interposed rigidifying spacers, serve to secure the sprocket members **69**, **70** to the flange **73**, in fixed coaxial

relation to one another on the sprocket hub **71**, as shown in FIG. 4.

Thus, a chain of power transmission is established, as illustrated in FIGS. 3, 4 and 5, from a prime mover (not shown) through pulley **47**, main drive shaft **46**, primary sprocket **59**, chain **60**, large diameter sprocket **61**, countershaft **54**, small diameter sprockets **64**, **65**, chains **68**, and large diameter sprockets **69**, **70** on main shaft **46**, whereby the sprocket hub **71**, as anti-friction journaled on shaft **46**, is driven at quite a great speed reduction and power torque increase ratio.

This drive is employed to rotatively power a cam unit, generally designated **74**, and through the latter, to cause horizontal reciprocating action of a plunger unit, generally designated by the reference numeral **76**, which includes oppositely disposed, rigidly interconnected hollow plunger heads **77**, in a manner to be described.

Referring to FIG. 3, the cam unit **74** comprises a single lobe-type cylindrical cam body **78** which is pivoted at **79** on the main shaft **46** with sufficient eccentricity to produce a desired horizontal reciprocatory throw of the plunger unit **76** in opposite directions. Cam body **78** is fixedly secured by a pin **81** and bolt **82** to the adjacent side of the sprocket hub **71** to rotate with the latter at the speed dropping and torque increasing ratio described above. Cam body **78** has a wear-resistant cylindrical steel sleeve **83** force fitted or shrunk thereon.

In accordance with the invention, an improved type of cradled, dual roller-type follower means is provided for coaction with the cam unit **74**, acting to drive both of the heads **77** of the plunger unit **76** with substantial advantages over prior crank and connecting rod types of plunger drive.

Referring to FIGS. 3 and 4, each head **77** pivotally mounts a follower roll carrier or cradle **85**, which is in the general form of a 90° yoke presenting pairs of arms **86**, **87** diverging from a central apex pivot, and at this pivot location the cradle has a pair of needle bearings **88** journaling it on a transverse pivot pin, in the form of a stud **89** extending through opposed walls of the tubular plunger head **77**, as best shown in FIG. 4. The respective pairs of yoke arms **86**, **87** each receive a transverse journal pin **90**, upon which an anti-friction follower roller **91** is journaled by a needle bearing **92**.

The arrangement of the cradles **85** is such that, as illustrated in FIG. 3, the follower rolls **91** ride the periphery of the lobe of cam sleeve **83** continuously, their respective cradles **85** swinging about the pivot pins **89**; and the result is to drive the plunger unit **76** and its attached plunger heads **77** in a smooth fashion, with an absolute minimum of side or transverse thrust upon the heads.

Referring to FIG. 4, the arrangement of the cradled pair of cam follower rolls **91** on each plunger head **77** is offset in a manner to bring the line of force from cam unit **74** directly axially of the head; and this use of two pairs of rolls **91**, one at each side of the cam unit **74**, results in the elimination of connecting rods, their wrist pins and eccentric straps, plunger guides, and the like, as well as occasioning a minimum side thrust on the plunger head **77**, as indicated above, and its packing or sealing ring provisions, to be described. Since the pump **10** utilizes two opposed and spaced cylinders **33**, instead of a double-acting plunger and cylinder arrangement, no outer piston or plunger rod packings are required. The packing provisions of the improved pump exert of themselves the entire function of guiding the plunger heads within cylinders **33**, and without possibility of building up air pockets, as previously mentioned.

As illustrated in FIG. 3, the plunger unit **76**, in the zone between the roll cradles **85**, includes an elongated coupling yoke **93** integral at its opposite ends with the heads **77**. Yoke **93** is provided with an elongated horizontal slot **93'**, through which the main shaft **46** extends, thus accommodating the latter with a slight side clearance, adequate to prevent contact with the plunger unit **76** as the latter follows its horizontal reciprocating path.

As best shown in FIGS. 3 and 4, each plunger head **77** is provided within its cylinder **33** with an integral, reduced diameter shoulder extension **94**, upon which an annular cupped sealing ring **95** of V-shaped cross section is disposed for sealing coaction with the surface of cylinder liner **32**; and at a further reduced diameter zone, a sealing ring **96** is received, with an O-ring **97** in a groove of the ring to coact also with the liner. A second, outer sealing cup **98** is held in place directly outwardly of ring **96** by a washer **99**; and an apertured cup-like cap **100** in turn locks the entire assembly of such sealing members rigidly on the outer end of plunger head extension **94**.

The head **77** and extension **94** are provided with an axially extending central bore **102** with which an inner axial valve port **103** of head **77** communicates; and cap **100** is provided with an aligned center port **104** opening to the cylinder space **33** of the cylinder and manifold housing **14**. A valve check ball **107** is urged against the valve port or seat **103** by means of a coil compression spring **108** acting against the end cap **100**, for a purpose to be described after the nature of the remaining basic components of oil and water sub-systems of pump **10** has been made clear.

As shown in FIGS. 1 and 4 of the drawings, each housing **14** is cast or otherwise formed to provide an integral, laterally extending oil duct or manifold **110**, which communicates with the cylinder space **33** of the housing at an end opening **111** of said space; and the manifold **110** in turn opens through a side port **112** to the diaphragm unit **16**. Housing **14** also has an oil flow passage **114** through which it is adapted to be communicated with the oil pressure safety balancing or equalizing structure **24** shown in FIG. 6, as will be described.

As best shown in FIG. 1, the diaphragm unit **16** includes an upper dished housing head **115** and a lower dished housing head **116**, these heads defining a space which is separated by a flexible corrugated diaphragm **117**. The diaphragm is marginally clamped between annular flanges **118** of the housing members, through the agency of a pair of generally semi-circular clamp ring members **120**. As shown in FIG. 2, the diaphragm **117** is additionally held in place against the flange **118** of the upper head **115** by a ring **120'** and screws **120''** so as to prevent significant oil leakage if the opposite housing head **116** is removed for cleaning.

Clamp ring members **120** have outwardly projecting ears **121** (FIG. 2) which are apertured to receive clamp bolts or studs **122** taken up by wing nuts **123**; and the interior surface of each of the rings **120** is grooved or cupped in frustoconical cross section, as indicated in FIG. 1, thus to provide a wedging action as the studs **122** are taken up to draw the housing flanges **118** tightly toward one another and against the interposed margin of diaphragm **117**.

Thus, the diaphragm constitutes a pumping element sealing off the oil side of the pumping system from the side actually pumping the water on the lower side of diaphragm **117**, oil filling the chamber **124** above the diaphragm. A diaphragm chamber **125** beneath diaphragm **117** communicates through a water conduit member **127** with the distributing valve unit **18**, which will be hereinafter described in detail.

It is believed that the operation of the pump **10**, as described to this point, will be clear. With the unitarily connected plunger heads **77** reciprocated by cam unit **74**, a stroke of each toward the latter of a predetermined length occasions a vacuum in the cylinder **33** on the opposite or outer side of the head in question, causing the corresponding diaphragm **117** to rise under a corresponding vacuum in its upper oil cylinder **124**, and in turn draw water to be pumped into the lower diaghragm chamber **125**. As the plunger unit **76** changes travel direction, the water is discharged through conduit **127** under oil pressure applied across the entire area of the opposite side of dia-

phragm 117. The water is forced to the distributing valve unit 18, whence it is discharged externally of the system in a manner to be described. Water flows from the unit 18 into diaphragm chamber 125 on the vacuum stroke. The corrugated nature of the diaphragm 117 provides an adequate area for full flexure to its maximum extent, and also assists in clearing the diaphragm surface of possible adhering deposits.

Referring to FIGS. 3 and 4, the valving provisions, including the spring urged ball check 107 within the bore 102 of the plunger head extension 94, provide an automatic built-in compensation of oil pressure in the pressure and vacuum cycles of the plungers 77. Thus, when the pump is operated for a long period under conditions of high pressure and heavy load, a tendency of course develops for the oil on the pressure end of cylinder 33 to pass the plunger sealing provisions 95, 96, 97 to the low oil pressure side of the system, represented by the interior of casing 12; and this is apt to cause the high pressure side in cylinder 33, manifold 110 and diaphragm chamber 124 to lack oil in adequate quantity to maintain constant efficiency. Accordingly, the valving arrangements allow a momentary controlled return flow of oil through ball check port 103 to the high side of the plunger head at certain times when the latter is on its vacuum cycle. Thus, the sizes of the head port 103, the plunger extension cap port 104 and the ball 107 are proportioned in relation to the force of spring 108 in such manner that the latter may yield on the suction stroke, permitting oil to pass from the filled transmission casing 12 into the pressure side of cylinder 33, whenever the oil pressure in casing 12 reaches a predetermined value corresponding to the tension of spring, for example 30 pounds. This insures that the part of the system from cylinder 33 up to the diaphragm chamber 124 will be filled at all times with oil. There is no possibly of a build-up of an air pocket in this oil space which, due to the compressibility of the air, would prevent full attainment of the contemplated pumping output pressure.

The distributing unit 18 (reference being had to FIGS. 1, 2 and 2A) comprises an integral, cored out central housing member 128, of which the conduits 127 may be integral end extensions, having ports 129 at either lateral end thereof through which each conduit 127 opens to the interior of the unit 18.

This interior is subdivided into two like halves by an upright wall or partition 130, providing main entry and discharge manifold chambers 131 on opposite sides thereof for the reversing flow of water in vacuum and pressure cycles of plunger heads 77. Valve plates 132 and 133 are, respectively, disposed across the front and rear side of the central housing member 128, with sealing gaskets interposed, which plates are of an identical nature illustrated in FIG. 2A of the drawings, and the plates 132, 133 are, respectively, parts of water intake and water discharge housing structure at the front and rear sides of unit 18.

As shown in FIGS. 2 and 2A, the plates are generally rectangular in outline and each has a pair of laterally spaced valve ports 135 formed therein. Each such port is adapted to be closed by a flapper valve 136 suitably pivoted at 137 on one side thereof. A recessed intake valve housing member 138 clamps the intake valve plate 132 against the forward side of the central housing part 128; and the above mentioned intake fitting is formed as a part of valve housing 138, being connected by an appropriate conduit 139 with a source of water or other liquid to be pumped.

In similar fashion, a recessed discharge housing member 141 clamps the rear discharge valve plate 133 against the central housing portion 128; and discharge housing 141 is adapted to be connected at its own discharge fitting 22, as by an appropriate conduit 142, with a liquid disposal point. In addition, the rear discharge housing 141 is provided with a small tube 143, for a pressure balancing purpose to be described in connection with FIG. 6.

Referring again to FIG. 2, it seen that the flapper valve elements 136 of the forward, intake valve plate 132 are disposed to seat over the ports 135 of the latter from its rear; and the elements 136 of the rear, discharge valve plate 133 similarly coact with the latter from its rear.

Accordingly, upon successive suction strokes of the two pumping diaphragms 117, water or other liquid to be pumped is first drawn through the ports of plate 132 into the central manifold chambers 131 at each side of the partition 130, then, on the reverse, pressure throws of the diaphragms 117, discharged through the ports 135 of the other valve plate 133, and through the fitting 22 and discharge conduit or line 142.

The valve housing members 138 and 141 are cored to provide integral baffle elements 143' in alignment with their respective intake and discharge fittings 20 and 22, to avoid or minimize liquid turbulence which might interfere with proper valve action. They also reinforce the housing members 138, 141 to withstand high liquid pressure.

Now referring to FIG. 6, showing the oil pressure balancing and compensating unit 24, the latter is related in function to the valve provisions built into the plunger heads 77, but serves as an agency to protect against unbalanced high oil pressures on the high side of the system. Unit 24 is operatively connected to the respective opposite oil cylinders 33 of each of the cylinder and manifold housings 14 by a fitting 145 threadedly applied to the oil passage 114 of that housing, with flexible oil conduits 146 connecting from these points to a cast tubular housing body 147 of the unit 24. Thus the latter may be mounted at any desired position relative to the remaining symmetric units of pump 10.

Body 147 is cored and reamed to provide a lower control piston or plunger bore 148, in which a cylindrical steel liner sleeve 149 is fitted, and bore 148 opens downwardly into the upper oil chamber 150 of an upper, domed housing part 151 of a diaphragm housing 152 of pressure balancing unit 24. A flexible diaphragm 153 is marginally clamped between coacting flanges of the upper diaphragm housing half 151 and its lower half 154, which handles water, as by means of a pair of clamp rings 155 similar to the clamp rings 120 for the oil-water diaphragm units 16.

A fitting 157 centrally threaded into the bottom of housing part 154 receives the single balancing tube 143 appearing in FIGS. 1, 2 and 6, this tube opening into the water discharge housing 141 of the distributor valve unit 18.

As shown in FIG. 6, the balance control cylinder or sleeve 149 of housing body 147 slidably receives a piston or plunger 159 equipped with a sealing O-ring; and a tubular plunger stem 160 is fixedly connected to plunger member 159 atop the latter. A small passage 161 opens downwardly through the plunger to oil chamber 150. Stem 160 extends upwardly through an opening in a cross partition 162 of housing 147, in which opening the stem is slidably guided for up and down movement. The upper portion of the balancer housing 147 above partition 162 is formed to provide a valve cylinder 163 having annular internal, upper and lower grooves or channels 164, 165 surrounding the valve stem 160 in vertically spaced relation to one another.

Stem 160 is closed at its top, being provided with two series of circumferentially spaced side ports 167, 168 opening therethrough in a vertical spacing from one another corresponding to the vertical spacing of the circumferential channels 164, 165 from one another. The latter communicate respectively with lateral fittings 169 by which they are connected to the respective oil conduits 146 leading from the passage 114 of pump cylinder housings 14.

A hand knob 170 is threaded into the upper, reduced diameter part of housing 147, engaging downwardly

against a pressure plug 171 to adjustably regulate the compression of a coil spring 172 acting between plug 171 and the upper closed end of tubular stem 160. This enables a critical pressure to be set, at which the compensating, balancing or equalizing unit 24 will come into play.

The function of the unit 24 is to protect the system of pump 10 in the event of an unusually high pressure build-up in the discharge housing side 141 of the distributor valve unit 18. This results in the pressurization from beneath, through the balancing tube 143 connecting units 18 and 24, of the diaphragm 153 of the latter unit.

Thus, in the position of the parts shown in FIG. 10, with the pump cylinders 33 under normal operating pressure, the two high pressure conduits 146 are sealed from one another at the tubular stem 160 of plunger 159, the two circumferential series of ports 167, 168 of the latter being blocked by the valve bore 163 beneath the respective grooves or channels 164, 165 of that bore; and the setting of the hand knob 170 in such as to compress the spring 172 sufficiently to maintain this sealed condition under the normal operating discharge pressure.

However, when the pressure builds up enough, beneath diaphragm 153, above a preset critical pressure value in the upper oil chamber 150 of diaphragm housing 152, determined by adjustment of hub 170, the result is that the plunger 159 is raised until it contacts upwardly against the partition 162 which defines the upper limit of the cylinder bore 148. This brings the respective series of valve member ports 167, 168 into lateral alignment with the channels 164, 165, freely communicating the two oil conduits 146 with one another through these ports and channels or grooves, and also communicating the small passage 161 in plunger 159 with the conduits The result is that pressures are equalized in the two high sides of the system, whereupon spring 172 returns plunger stem 160 to the seal-off position of FIG. 10. Hand knob 170 can be manipulated as desired to select any maximum bypass pressure, at which the two cylinders are pressure-equalized to limit discharge pressure in distributor valve unit 18. Insofar as plunger 159 and its stem 160 are concerned, side pressures thereon are equalized.

Thus, should the main discharge line at the fitting 22 of discharge housing 141 be shut off while the pump is operating, as by intended operation of a manual nozzle or like valve (not shown), or accidentally closed, the equalizing unit 24 places the main plunger cylinders 33 into communication with one another, so as to eliminate the danger of a motor burn-out or a breakage of some vital part of the pump 10, proper. The pump merely idles at a low rate of current consumption; and the necessity of shutting off the pump's motor between operating cycles, as cycles of automobile washing or the like, is eliminated. Unit 24 also operates as a pulsation dampener, since its diaphragm 153, in moving against the bias of spring 172 under discharge pulse peaks, and then returning, tends to even out the discharge flow.

For the rest, each pump cylinder space 33, hence manifold passage 110 to diaphragm unit 16 and balance conduit 146 to balancing unit 24, is adapted to be filled with oil, independently of the oil level in the cam and differential casing 12, through an upper passage 172' normally closed by a plug 173. The casing 12 is in turn adapted to be independently filled and replenished with oil at a top filler opening normally closed by a plug 174 (FIGS. 1 and 2), and to be drained at an opening at its bottom normally closed by a plug 175. Likewise, water may be drained from each of the diaphragm housings of the pump units 16 through an opening adjacent the bottom thereof closed by a plug 176 (FIG. 6), while oil may be drained from the opposite side of the diaphragm through openings 177.

As in the case of the diaphragm pump unit 16, and the main pump plunger heads 77, unit 24 is, above its diaphragm 153, free of corrosive, adhesive or other effect tending to hinder free movement of working parts, all of which are sealed in oil, and, accordingly, all are well lubricated. As above indicated, any possible tendency to leak oil pressure past the sealing ring provisions of the head 77 is automatically compensated by flow of oil past the internal sealing provisions of the head upon its suction stroke, should the pressure in main casing 12 increase predeterminedly.

The cam and cam follower structure 74 and 85 of pump 10' (FIGS. 3 and 4) as united in a unitary, double-headed plunger device 76, permits a substantially friction free operation of the pressure plungers, without wasteful side thrust, and also eliminates the need for rod packing and guide provisions usually required in double acting plunger and cylinder units.

In general, the pump 10 is simple, compact and sturdy in its parts, providing a dual combination of reciprocating plunger and pumping diaphragm units having fully as great pumping capacity and efficiency as, or greater than, any previous type of plunger pump, or diaphragm pump, or combination of plunger and diaphragm features, of which we are aware.

What we claim as our invention is:

1. A plunger-diaphragm type pump structure, comprising a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space to discharge a pressure fluid from an end of said space, a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism, said drive unit comprising a follower device pivotally mounted on each of said heads in radial relation to said cam, each follower device comprising a cradle pivoted on a plunger head, each cradle having means journaling a pair of follower rolls thereon in laterally spaced relation to one another for simultaneous rolling engagement with a lobe surface of said cam, and a diaphragm unit having diaphragm means in communication with said cylinder spaces to be operated by said pressure fluid, said diaphragm unit in turn pressurizing a fluid to be pumped.

2. A plunger-diaphragm type pump structure, comprising a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space to discharge a pressure fluid from an end of said space, a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism, said plunger heads having a yoke rigidly coupling the same together for reciprocatory movement as a unit, said drive comprising a pair of follower devices mounted on said coupling yoke in radial relation to said cam, each follower device comprising a cradle pivoted on said yoke, each cradle having means journaling a pair of follower rolls thereon in laterally spaced relation to one another for simultaneous rolling engagement with a lobe surface of said cam, and a diaphragm unit having diaphragm means in communication with said cylinder spaces to be operated by said pressure fluid, said diaphragm unit in turn pressurizing a fluid to be pumped.

3. The pump structure of claim 1, in which said diaphragm unit comprises a pair of housings each communicating with one of said cylinder spaces and having a flexible diaphragm pressurized by said pressure fluid.

4. The pump structure of claim 2, in which said diaphragm unit comprises a pair of housings each communicating with one of said cylinder spaces and having a flexible diaphragm pressurized by said pressure fluid.

5. A pump comprising a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space, and a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism, said drive unit comprising a follower device pivotally mounted on each of said heads on opposite sides of said cam, each follower device comprising a cradle pivoted on a plunger head, each cradle having means journalling a pair of follower rolls thereon in laterally

spaced relation to one another for simultaneous rolling engagement with a lobe surface of said cam, and an oil casing in which said cam is journaled to rotate in oil, said cylinder spaces communicating inwardly of said plunger heads with said casing beneath the level of oil therein, said plunger heads each having a valved passage therethrough, through which passage each cylinder space is adapted to be communicated with the interior of said casing on a non-pumping stroke of the plunger head.

6. A pump comprising a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space, and a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism, said plunger heads having a yoke rigidly coupling the same together for reciprocatory movement as a unit, said drive unit comprising a pair of follower devices mounted on said coupling yoke on opposite sides of said cam, each follower device comprising a cradle pivoted on said yoke, each cradle having means journaling a pair of follower rolls thereon in laterally spaced relation to one another for simultaneous rolling engagement with a lobe surface of said cam, and an oil casing in which said cam is journaled to rotate in oil on an axis passing transversely through said yoke, said cylinder spaces communicating inwardly of said plunger heads with said casing beneath the level of oil therein, said plunger heads each having a valved passage therethrough, through which passage each cylinder space is adapted to be communicated with the interior of said casing on a non-pumping stroke of the plunger head.

7. In a pump of the combined plunger and diaphragm type characterized by a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space, and a flexible pumping member in communication with one of said respective spaces and subject to alternate pressurization and pumping movement on a pumping stroke of one of said plungers, and a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism; the improvement comprising an oil casing in which said cam and cam follower devices are journaled to rotate in oil, said cylinder spaces communicating inwardly of said plunger heads with said casing beneath the level of oil therein, said plunger heads each having a valved passage therethrough through which said cylinder spaces and flexible pumping members are adapted to be communicated with the interior of said casing and beneath the oil level therein on non-pumping strokes of the respective plunger heads.

8. In a pump of the combined plunger and diaphragm type characterized by a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space, and a flexible pumping member in communication with one of said respective spaces and subject to alternate pressurization and pumping movement on a pumping stroke of one of said plungers, and a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism; the improvement comprising a follower device pivotally mounted on each of said heads on opposite sides of said cam, each follower device comprising a cradle pivoted on a plunger head, each cradle having means journaling a pair of follower rolls thereon in laterally spaced relation to one another for simultaneous rolling engagement with a lobe surface of said cam, an oil casing in which said cam and cam follower devices are journaled to rotate in oil, said cylinder spaces communicating inwardly of said plunger heads with said casing beneath the level of oil therein, said plunger heads each having a valved passage therethrough through which said cylinder spaces and flexible pumping members are adapted to be communicated with the interior of said casing and beneath the oil level therein on non-pumping strokes of the respective plunger heads.

9. In a pump of the combined plunger and diaphragm type characterized by a pair of reciprocatory plunger units each including a plunger head operating in a cylinder space, and a flexible pumping member in communication with one of said respective spaces and subject to alternate pressurization and pumping movement on a pumping stroke of one of said plungers, and a drive unit including a lobe cam common to said plunger units to operate the plunger heads in synchronism, said plunger heads having means rigidly coupling the same together for reciprocatory movement as a unit; the improvement comprising a follower device on each of the opposite sides of said cam, each follower device comprising a cradle pivoted on said coupling means, each cradle having means journaling a pair of follower rolls thereon in laterally spaced relation to one another for simultaneous rolling engagement with a lobe surface of said cam, an oil casing in which said cam and cam follower devices are journaled to rotate in oil, said cylinder spaces communicating inwardly of said plunger heads with said casing beneath the level of oil therein, said plunger heads each having a valved passage therethrough through which said cylinder spaces and flexible pumping members are adapted to be communicated with the interior of said casing and beneath the oil level therein on non-pumping strokes of the respective plunger heads.

10. A pump structure comprising a pair of diaphragm units each including head members and a flexible diaphragm clamped therebetween to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, said unit having means to connect the first chamber thereof with a source of pressure liquid and means to connect the second chamber thereof with a liquid pumped by the pump, with the diaphragm thereof pressurized over the entire area of both sides thereof by the pressure liquid and the pumped liquid, said diaphragm unit having a ring clamping the diaphragm thereof to the head member thereof on its pressure liquid side, and means to clamp the last named head member and said clamp ring against the other head member of the diaphragm unit, a pump unit constituting said source of pressure liquid and supplying the liquid to the first chamber of each of said diaphragm units, and balancing valve means to connect the respective first chambers of said diaphragm units with the output of said pump unit in response to variations in pressure in said first chambers.

11. A pump structure comprising a pair of diaphragm units each including head members and a flexible diaphragm clamped therebetween to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, each of said units having means to connect the first chamber thereof with a source of pressure liquid and means to connect the second chamber thereof with a liquid pumped by the pump, with the diaphragm thereof pressurized over the entire area of both sides thereof by the pressure liquid and the pump liquid, said diaphragm units each having a ring clamping the diaphragm thereof to the head member thereof on its pressure liquid side, and split ring means to wedgingly clamp the last named head member and said clamp ring against the other head member of the diaphragm unit, a pump unit constituting said source of pressure liquid and supplying the liquid to the first chamber of each of said diaphragm units, and balancing valve means to connect the respective first chambers of said diaphragm units with the output of said pump unit in response to variations in pressure in said first chambers.

12. A pump comprising a pair of diaphragm units each including head members and a flexible diaphragm clamped therebetween to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, each of said units having means to connect the first chamber thereof with a source of pressure liquid and means to connect the second chamber thereof with a liquid pumped by the pump, with the diaphragm thereof pressurized over the entire area thereof by the pressure liquid pressure, and a balancing unit to equalize the pressure in said first diaphragm chambers

under a pressure of the liquid pumped, said balancing unit comprising a valve device having connections adapted to be opened to inter-communicate the pressures of the respective first pumping chambers, and means subject to the pressure of the liquid pumped and operable upon said valve device in response to said excessive pressure to open said connections.

13. A pump comprising a pair of diaphragm units each including head members and a flexible diaphragm clamped therebetweeni to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, each of said units having means to connect the first chamber thereof with a source of pressure liquid and means to connect the second chamber thereof with a liquid pumped by the pump, with the diaphragm thereof pressurized over the entire area thereof by the pressure liquid pressure, said diaphragm units each having a ring clamping the diaphragm thereof to the head member thereof on its pressure liquid side, and means to clamp the last named head member and said clamp ring against the other head member of the diaphragm unit, and a balancing unit to equalize the pressure in said first diaphragm chambers under a pressure of the liquid pumped, said balancing unit comprising a valve device having connections adapted to be opened to inter-communicate the pressures of the respective first pumping chambers, and means subject to the pressure of the liquid pumped and operable upon said valve device in response to said excessive pressure to open said connections.

14. A pump comprising a pair of opposed, axially aligned cylinders, a plunger reciprocable in each cylinder to pump a pressure liquid therefrom, a pair of secondary pumping units each including a flexible pressure responsive member separating the unit into first and second pumping chambers sealed from one another by said member, conduit means connecting said first chambers with the respective cylinders for pressurization of said flexible member by said pressure liquid on pumping strokes of said plungers, a distributor valve unit common to said secondary pumping units having conduit means connecting the same to said units at the respective second chambers of the latter, said distributor unit having a pair of reverse liquid flow chambers communicating with said last named conduit means, liquid intake and discharge housings, and automatic valve means separating said reverse flow chambers from the respective intake and discharge housings for the intake and discharge flow of a pumped liquid through said reverse flow chambers and last named conduit means upon reversing action of said plungers, thus to alternately pressurize and depressurize said flexible pressure responsive members, and a balancing unit to equalize the pressure in said respective cylinders and first chambers under an excessive pressure in the discharge housing of said distributor unit, said balancing unit comprising a valve device having connections adapted to be opened to inter-communicate the pressures of the respective cylinders and first chambers, and means subject to pressure in said discharge housing and operable upon said valve device in response to said excessive pressure in the discharge housing to open said connections.

15. A pump comprising a pair of opposed, axially aligned cylinders, a plunger reciprocable in each cylinder to pump a pressure liquid therefrom, a pair of diaphragm units each including head members and a flexible diaphragm clamped between said members to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, conduit means connecting said first chambers with the respective cylinders for pressurization of the respective diaphragms over the entire area thereof by said pressure liquid on pumping strokes of said plungers, a distributor valve unit common to said diaphragm units having conduit means connecting the same to said units at the respective second chambers of the latter, said distributor unit having a pair of reverse liquid flow chambers communicating with said last named conduit means, liquid intake and discharge housings, and automatic valve means separating said reverse flow chambers from the respective intake and discharge housings for the intake and discharge flow of a pumped liquid through said reverse flow chambers and last named conduit means upon reversing action of said plungers, thus to alternately pressurize and depressurize said diaphragms, and a balancing unit to equalize the pressure in said respective cylinders and first chambers under an excessive pressure in the discharge housing of said distributor unit, said balancing unit comprising a valve device having connections adapted to be opened to intercommunicate the pressures of the respective cylinders and first chambers, and means subject to pressure in said discharge housing and operable upon said valve device in response to said excessive pressure in the discharge housing to open said connections.

16. A pump comprising a pair of opposed, axially aligned cylinders, a plunger reciprocable in each cylinder, said plungers being rigidly coupled for reciprocation in unison to pump a pressure liquid from said respective cylinders, a pair of diaphragm units each including head members and a flexible diaphragm clamped therebetween to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, conduit means connecting said first chambers with the respective cylinders for pressurization of the respective diaphragms over the entire area thereof by said pressure liquid on pumping strokes of said plungers, a distributor valve unit common to said diaphragm units having conduit means connecting the same to said units at the respective second chambers of the latter, said distributor unit having a pair of reverse liquid flow chambers communicating with said last named conduit means, liquid intake and discharge housings, and automatic valve means separating said reverse flow chambers from the respective intake and discharge housings for the intake and discharge flow of a pumped liquid through said reverse flow chambers and last named conduit means upon reversing action of said plungers, thus to alternately pressurize and depressurize said diaphragms, and a balancing unit to equalize the pressure in said respective cylinders and first diaphragm pumping chambers under an excessive pressure in the discharge housing of said distributor unit, said balancing unit comprising a valve device having connections adapted to be opened to inter-communicate the pressures of the respective cylinders and first pumping chambers, and means subject to pressure in said discharge housing and operable upon said valve device in response to said excessive pressure in the discharge housing to open said connections.

17. A pump comprising a pair of reciprocatory plunger units each including a plunger head operating radially in a cylinder space, and a drive unit radially inwardly of said plunger units, said drive unit including a rotary cam common to said plunger units to operate the plunger heads in synchronism to discharge fluid radially outward of said cylinder spaces, said drive unit comprising a follower device pivotally mounted on each of said heads, each follower device comprising a cradle pivoted on a plunger head, each cradle having means journaling a pair of follower rolls thereon in laterally spaced relation to one another for simultaneous rolling engagement with a surface of said cam.

18. The pump of claim 17, in which said plunger heads have a yoke rigidly coupling the same together for reciprocatory movement as a unit.

19. A pump structure comprising a diaphragm unit including head members and a flexible diaphragm clamped therebetween to provide first and second pumping chambers in each diaphragm unit sealed from one another by said diaphragm, said unit having means to connect the first chamber thereof with a source of pressure liquid and means to connect the second chamber thereof with a liquid pumped by the pump, with the diaphragm there-

of under pressure over the entire area of both sides thereof by the pressure liquid and the pumped liquid, a pump unit constituting said source of pressure liquid and supplying the liquid to the first chamber of each of said diaphragm units, and balancing valve means to connect the respective first chambers of said diaphragm units with the output of said pump unit in response to variations in pressure in said first chambers.

20. A pump comprising a pair of diaphragm units each including head members and a flexible diaphragm clamped therebetween to provide first and second chambers in each diaphragm unit sealed from one another by said diaphragm, each of said units having the diaphragm thereof operated on the side of the first chamber thereof from a source of pressure liquid, and means to connect the second chamber thereof with a liquid pumped by the pump, and a balancing unit to equalize the pressure in said first diaphragm chambers under a pressure of the liquid pumped, said balancing unit comprising a valve device having connections adapted to be opened to intercommunicate the pressures of the respective first pumping chambers, and means subject to the pressure of the liquid pumped and operable upon said valve device in response to said excessive pressure to open said connections.

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