March 10, 1936. W. FERRIS 2,033,464

PUMP AND MOTOR

Filed May 8, 1933 6 Sheets-Sheet 1

Fig. 1.

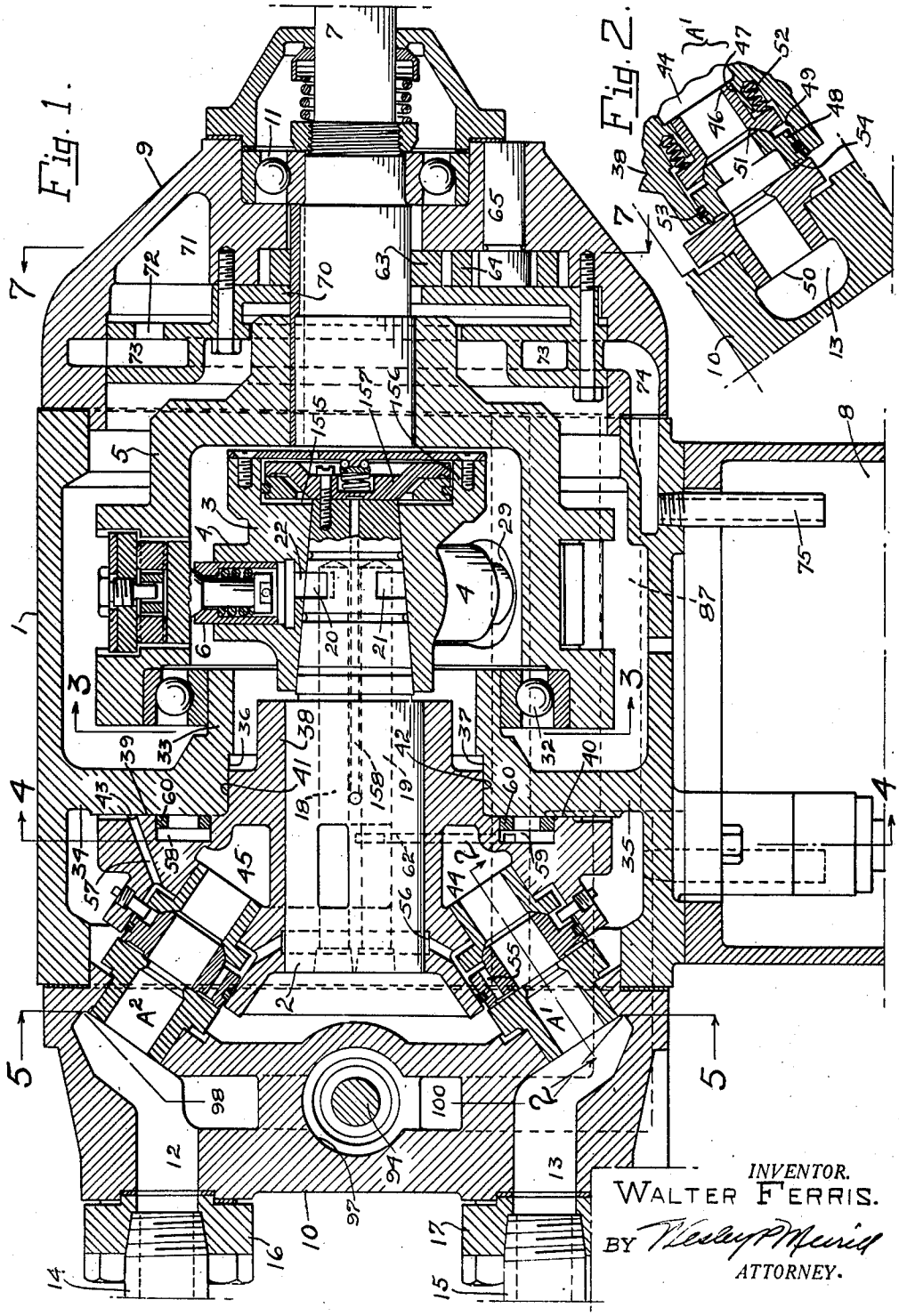


Fig. 2.

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PUMP AND MOTOR

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Fig. 3.

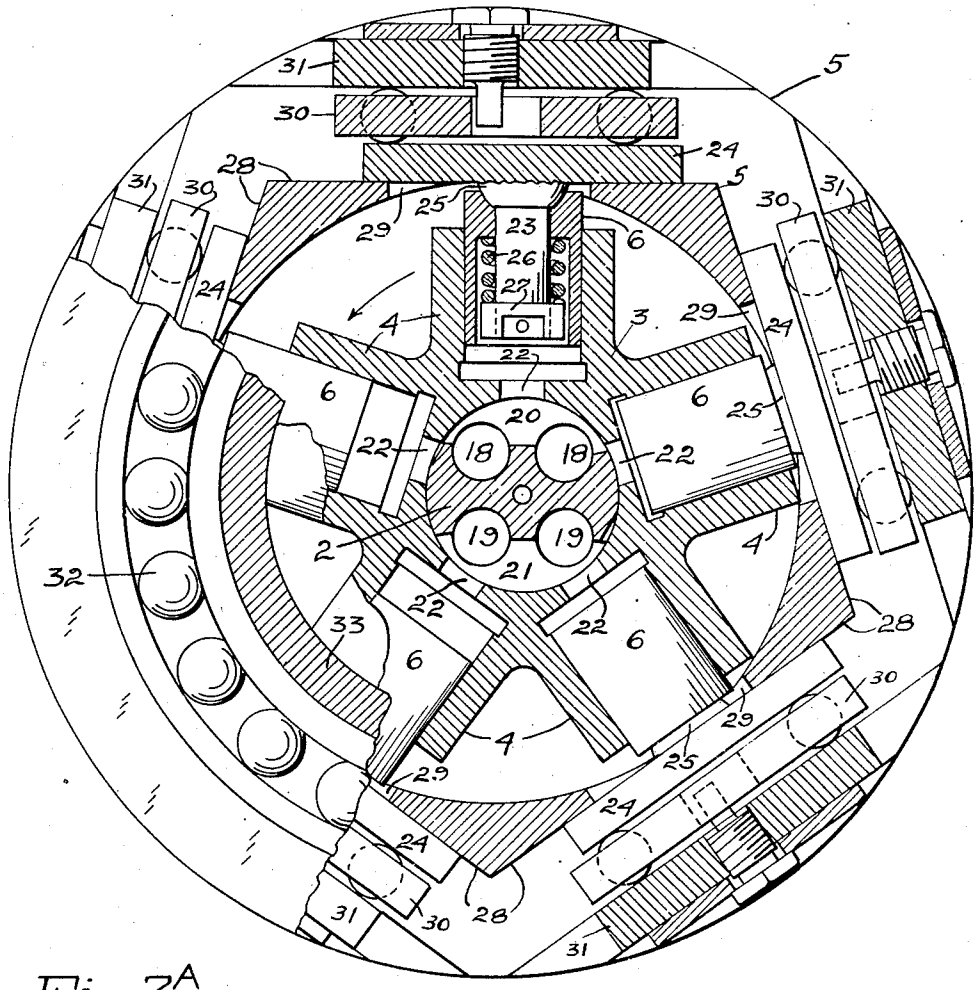
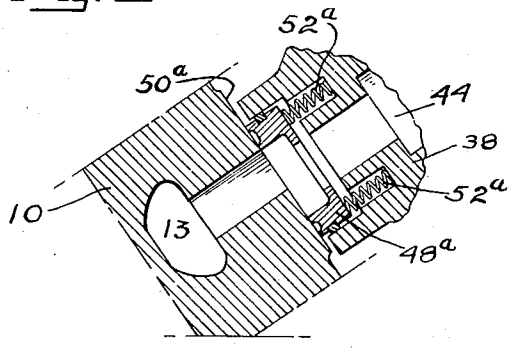


Fig. 2A



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PUMP AND MOTOR

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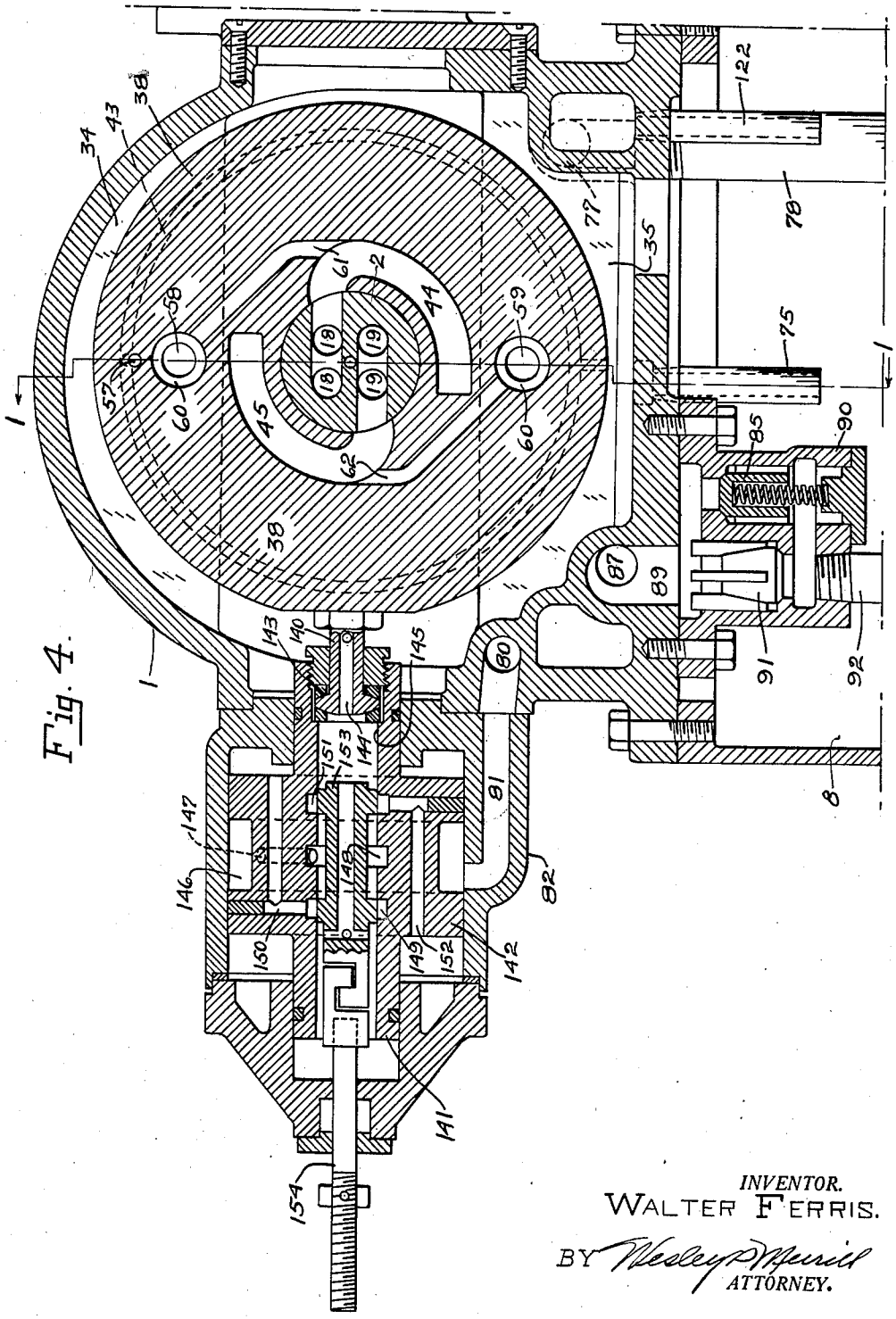


Fig. 4.

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PUMP AND MOTOR

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Fig. 5.

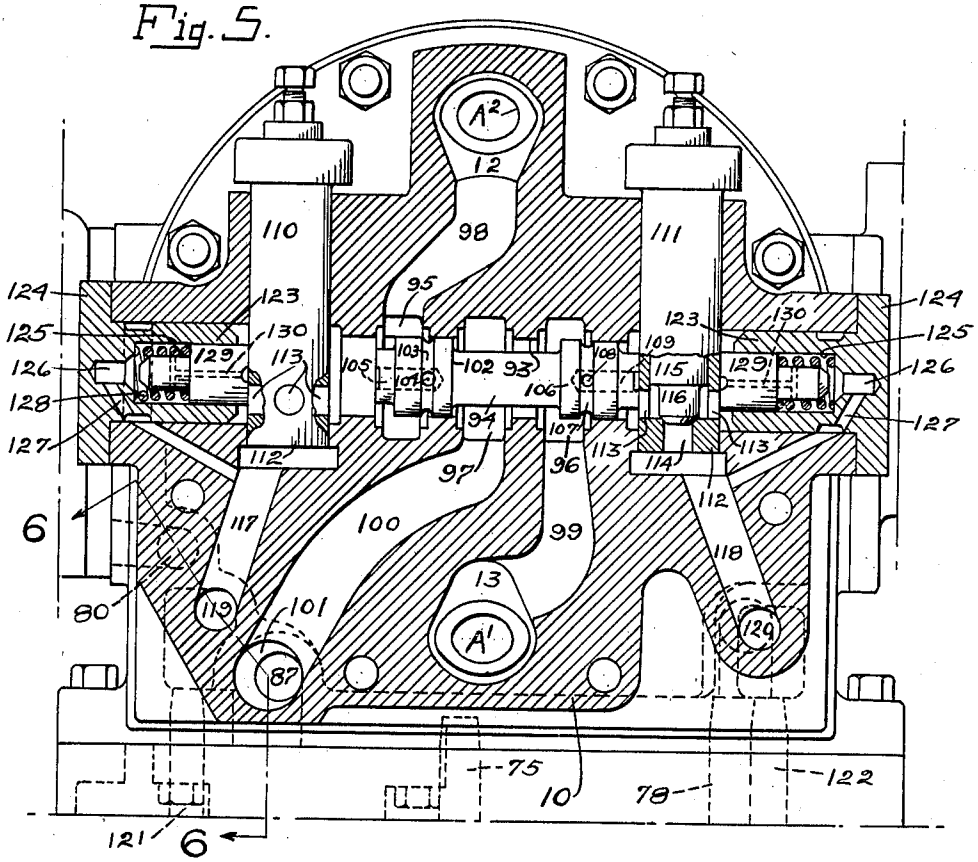
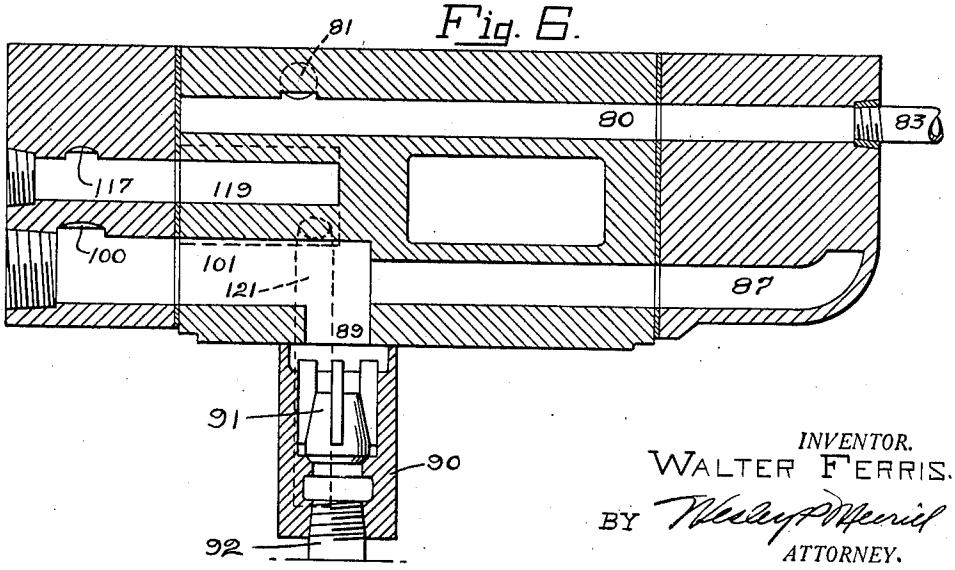


Fig. 6.



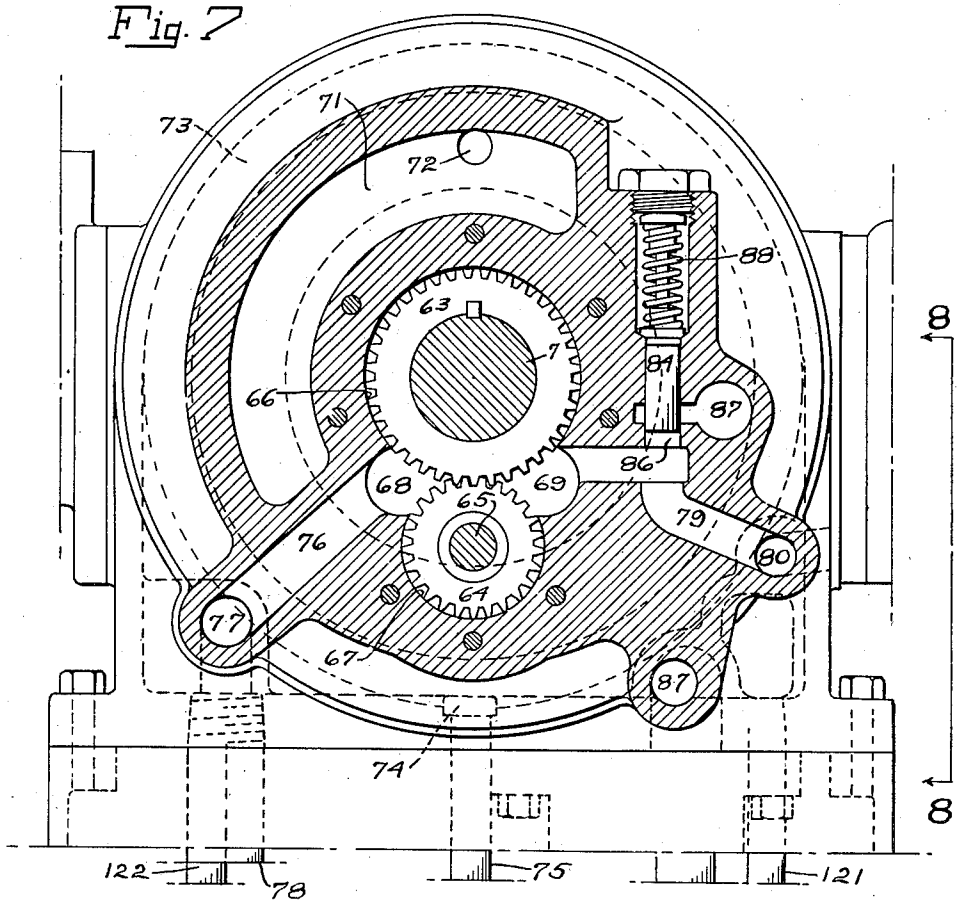
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PUMP AND MOTOR

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Fig. 7



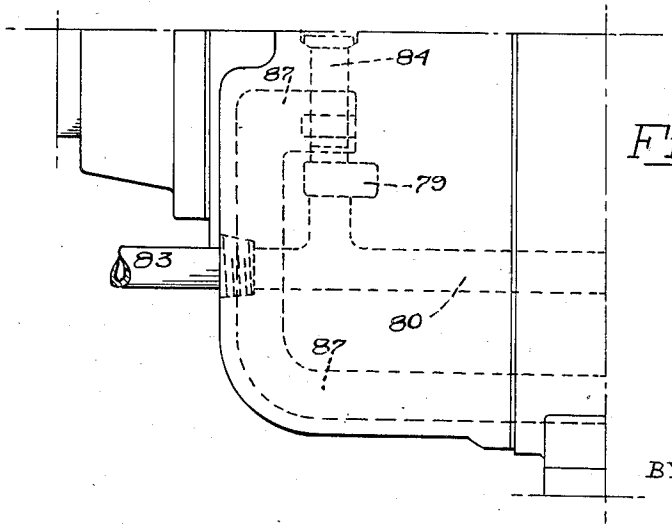


Fig. 8.

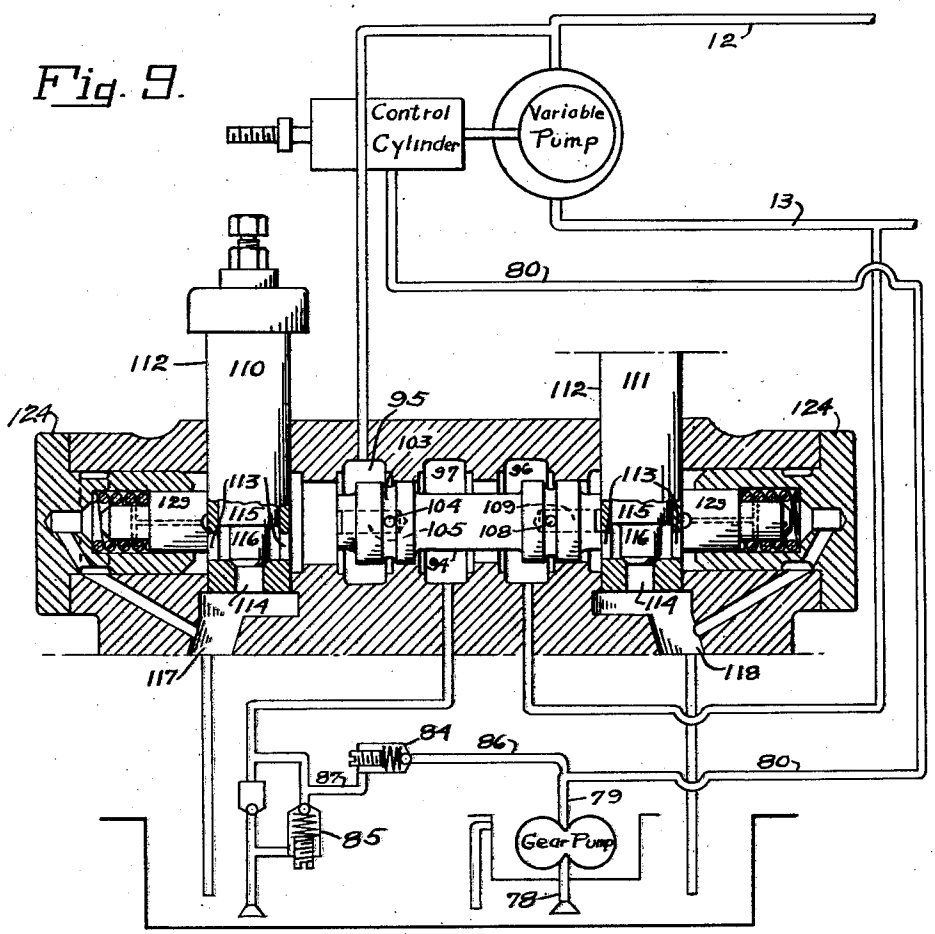
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PUMP AND MOTOR

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Fig. 9.



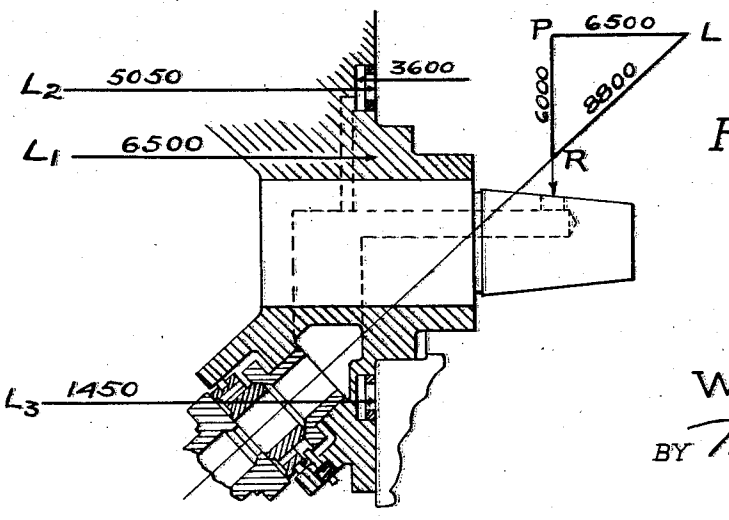


Fig. 10.

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Patented Mar. 10, 1936 2,033,464

UNITED STATES PATENT OFFICE

2,033,464

PUMP AND MOTOR

Walter Ferris, Milwaukee, Wis., assignor to The Oilgear Company, Milwaukee, Wis., a corporation of Wisconsin

Application May 8, 1933, Serial No. 669,861

25 Claims. (Cl. 103—161)

This invention relates to rotary hydraulic pumps and motors of the type in which a rotary cylinder barrel is provided with radial cylinders having pistons fitted therein, the cylinder barrel is journaled upon a pintle which is supported at only one of its ends and through which liquid flows to and from the cylinders, a thrust member is arranged around the cylinder barrel eccentric thereto and coacts with the pistons to convert rotary mechanical motion into a flow of liquid or vice versa, and the piston displacement is varied by moving the pintle to vary the distance between the axis of the cylinder barrel and axis of the thrust member.

The pump or motor to which the invention applies in particular has its pintle provided at the rear end thereof with a pintle block which is fitted between stationary guides or ways and is slidable therebetween to vary pump displacement.

The forces required to convert rotary mechanical motion into a flow of liquid or vice versa are transmitted through the pistons from or to the thrust member and act in a radial plane upon the pintle and tend to deflect it. These radial forces urge the pintle toward the low pressure side of the pump or motor and create high bearing pressures between the pintle block and the axial faces of the supporting guides and, since the pintle is supported at only one of its ends, the axial components of these forces create high bearing pressures between the pintle block and the radial faces of the supporting guides. These bearing pressures are often so high that excessive wear results, and also considerable force is required to adjust the pintle when the pump or motor is operating at high pressures.

This invention has as an object to provide a pump or motor in which the pintle is hydrostatically balanced.

Another object is to provide a pump or motor in which the bearing pressure exerted by the pintle block upon the guides is reduced.

Another object is to provide a pump or motor which may have its displacement easily and readily changed while operating at high pressures.

Another object is to provide a hydraulic machine which may be operated in either direction and either as a pump or as a motor and which has its pintle hydrostatically balanced regardless of the direction of operation or the function of the machine.

The invention is exemplified by the hydraulic machine shown in the accompanying drawings in which the views are as follows:

Fig. 1 is a longitudinal vertical section taken through the machine on the irregular line 1—1 of Fig. 4.

Fig. 2 is a section taken on the line 2—2 of Fig. 1 to show the details of a sliding joint.

Fig. 2A is a view similar to Fig. 2 but showing a modified form of sliding joint.

Fig. 3 is a transverse section taken on the line 3—3 of Fig. 1 and showing the pump rotor partly in full and partly in section.

Fig. 4 is a transverse section taken on the line 4—4 of Fig. 1.

Fig. 5 is a transverse section taken on the irregular line 5—5 of Fig. 1.

Fig. 6 is a detail section taken on the irregular line 6—6 of Fig. 5.

Fig. 7 is a transverse section taken on the line 7—7 of Fig. 1.

Fig. 8 is a detail view taken on the line 8—8 of Fig. 7.

Fig. 9 is a circuit diagram.

Fig. 10 is a force diagram.

The machine comprises, in general, a closed casing 1, a pintle 2 arranged within the casing, a cylinder barrel 3 journaled upon the pintle and provided with a plurality of cylinders 4, a thrust member or driver 5 arranged around the cylinder barrel, a piston 6 arranged in each cylinder and coacting with the thrust member to transmit forces between it and the liquid in the cylinder, and a shaft 7 connected to the thrust member and extending through one end of the casing.

When the shaft 7 is driven from an outside source of power, the thrust member will reciprocate the pistons in the cylinders and rotate the cylinder barrel upon the pintle and cause the machine to function as a pump and, when liquid under pressure is delivered to the cylinders, it will reciprocate the pistons in the cylinders and thereby rotate the thrust member and the shaft and cause the machine to function as a motor.

The machine will thus function as either a pump or a motor but, since means are herein provided for controlling the stroke and for flooding the low pressure side with liquid which are not necessary when it is employed as a motor, it will be described herein as a pump and it is to be understood that the terms "pump" and "motor" as employed herein are substantially synonymous within the purview of the present invention.

When the machine is employed as a pump, it is also provided with a reservoir 8 which contains a supply of liquid and is shown arranged beneath the casing 1 and connected thereto to support the same.

The casing 1 is provided at its front end with a removable head 9 and at its rear end with a removable head 10. The head 9 closes the front end of the casing and carries an antifriction bearing 11 to support the shaft 7, and the head 10 closes the rear end of the casing and has two main fluid passages 12 and 13 formed therein. The passages 12 and 13 may be connected, respectively, to two pipes 14 and 15 of an external circuit by two pipe fittings 16 and 17 which are fastened to the rear head 10.

The passages 12 and 13 communicate, in a manner to be presently described, with fluid passages formed in the pintle 2 longitudinally thereof, the lower passage 13 communicating with two upper pintle passages 18 and the upper passage 12 communicating with two lower pintle passages 19.

The passages 18 and 19 communicate, respectively, at the front ends thereof with two pintle ports 20 and 21 formed diametrically opposite each other in the front part of the pintle 2 which is tapered as shown in Fig. 1.

The cylinder barrel 3 is fitted upon the tapered part of the pintle and provided with a cylinder port 22 for each of the cylinders 4. Each port 22 registers with the pintle ports 20 and 21 alternately as the cylinder barrel rotates to permit liquid to flow into its cylinder during one part of a revolution of the cylinder barrel and to enable the piston 6 in that cylinder to eject liquid therefrom through the other pintle port during another part of a revolution of the cylinder barrel.

As shown in Fig. 3, each of the pistons 6 is hollow and provided with a piston pin 23 which is connected at its outer end to a crosshead 24 and provided with a spherical head 25 which engages a concave seat formed in the outer end of the piston.

The piston is closed at its outer end by the head 25 which is retained in firm engagement with its seat by a helical compression spring 26 arranged around the pin 23 between the inner face of the piston head and a collar 27 fixed on the inner end of the pin 23.

Each crosshead 24 engages a bearing face 28 which is formed upon the thrust member or driver 5 substantially at right angles to the piston axis and provided at its center with an opening 29 through which the head 25 of the piston pin 23 extends.

The crosshead 24 is engaged upon its outer face by a roller bearing 30 arranged between it and a bearing plate 31 which is carried by the driver 5 in a fixed position parallel to the bearing face 28.

Each piston is thus positively retained at a fixed distance from the axis of the driver and, when the axis of the driver is offset from the axis of the pintle and the driver is rotated, the pistons will be reciprocated in the cylinders and the cylinder barrel will be rotated upon the pintle.

The driver 5 is supported at its front end by the shaft 7 and at its rear end by a ball bearing 32 carried by a hollow hub 33 which surrounds the pintle 2 and is formed upon the front of an upper transverse way or pintle guide 34 and a lower transverse way or pintle guide 35.

The pump rotor thus far described is of well known construction and has not been illustrated nor described in detail herein, as a rotor of the same general type is fully illustrated and described in Patent No. 1,578,233.

The pump is shown with the axis of the pintle 2 and the axis of the shaft 7 arranged in a horizontal plane whereby horizontal movement of the pintle 2 will vary pump displacement, but the pump will operate when placed in any position. Hence, the terms used herein to denote direction are not limitations but simply refer to the positions shown.

The pintle guides 34 and 35 are ordinarily formed integral, respectively, with the upper and lower walls of the casing 1 and are provided with vertical rear faces to restrain the pintle from forward movement. The upper guide 34 is provided upon its lower edge with a bearing face 36 which extends across the casing 1 in substantially a horizontal plane and at right angles to the pintle axis. The guide 35 is ordinarily arranged directly below the guide 34 and is provided upon its upper edge with a bearing face 37 which is parallel to the bearing face 36. The bearing faces 36 and 37 form a transverse guideway and restrain the pintle from vertical movement.

The pintle 2 is provided upon its rear part with a pintle block 38 which may be formed integral therewith but which is ordinarily made separate and rigidly secured thereon to form substantially a part thereof and to provide an oil-tight joint therewith.

The pintle block 38 is reduced in cross-sectional area intermediate its ends to permit its front part to be closely fitted between the guides 34 and 35 and to provide an upper vertical bearing face 39 to engage the vertical rear face of the guide 34, a lower vertical bearing face 40 to engage the vertical rear face of the guide 35, an upper horizontal bearing face 41 to engage the bearing face 36 on the guide 34, and a lower bearing face 42 to engage the bearing face 37 on the guide 35.

The upper and lower horizontal bearing faces 41 and 42 are made relatively narrow as the hydraulic forces which act on the pintle block 38 and are so proportioned that their vertical components nearly cancel each other, leaving to the horizontal guide faces 41 and 42 only the function of definitely locating the pintle block vertically and supporting its weight, together with any residual vertical forces which may result from errors in computing the principal hydrostatic forces or in manufacturing the parts. As will appear later, the large guide reactions are horizontal and land against the broad vertical faces of the guides 34 and 35.

The bearing faces on the pintle block and on the pintle guides are lubricated by oil supplied thereto through a circular oil groove 43 which is formed in the pintle block as shown in Figs. 1 and 4.

In order that the pintle may be hydrostatically balanced, the pintle block 38 (Figs. 1 and 4) has formed therein two main passageways 44 and 45 each of which communicates with the pintle passages on one side of the pintle axis and curves around the pintle to the other side of the pintle axis and then communicates through a sliding joint A with the corresponding main passage in the rear head 10, the pintle passages 18 being connected by the passage 44 and a sliding joint A^1 to the passage 13, and the pintle passages 19 being connected by the passage 45 and a sliding joint A^2 to the passage 12.

The sliding joints A^1 and A^2 are exactly alike and may be constructed as shown in Figs. 1 and 2 or as shown in Fig. 2A. The joint A^1 (Figs. 1 and 2) is formed by a slidable thimble 46 which is fitted in a bore 47 formed in the pintle block 38 in communication with the passage 44, a center thimble 48 which is fitted in a counterbore 49 formed in the pintle block 38

concentric with the bore 47, and a fixed thimble 50 which is fixed in the rear head 10 in communication with the passage 13 and forms an oil-tight joint with the head 10.

The thimble 50 is ordinarily provided to insure a smooth bearing surface for the thimble 48 to bear against and to slide upon, but the thimble 50 may be omitted and the head 10 provided with a smooth bearing surface 50a (Fig. 2A) around the end of each of the passages 12 and 13.

The adjacent ends of the thimbles 46 and 48 are shaped to form a substantially oil-tight spherical joint 51 and are kept in contact with each other by helical compression springs 52 which engage the flange of the thimble 46 and are arranged in recesses formed in the pintle block.

The center thimble 48 is provided upon its periphery with a packing ring 53 which forms an oil-tight joint with the wall of the counterbore 49. The outer end of the thimble 48 is held by the springs 52 in contact with the flange of the fixed thimble 50 and provided with a limit groove 54 which limits the area upon which high pressure liquid may act and is drained into the inner end of the counterbore 49 by a duct 55 extending axially through the side wall of the thimble.

The counterbore 49 of the joint A^1 is connected at its inner end to the counterbore 49 of the joint A^2 by a semi-circular duct 56 which is formed in the pintle block and extends around the pintle as shown in Fig. 1, and the counterbore 49 of the joint A^2 is connected by a duct 57 to the oil groove 43 in the face of the pintle block so that leakage from the sliding joint on the high pressure side of the pump will keep the counterbore 49 on the low pressure side of the pump flooded with liquid and will also supply lubricant for the bearing faces on the pintle block and on the pintle guides.

Each sliding joint has the bores of all three of its thimbles arranged in axial alinement when the pintle 2 is in its central or neutral position, but when the pintle is moved in either direction from its central position, the bores of the thimbles 46 and 48 are offset from the bore of the thimble 50.

In order that liquid may pass freely through the sliding joint in any position of the pintle, the thimble 48 has the outer part of its bore elongated in a direction parallel to the guides 34 and 35 and extended an equal distance upon each side of the axis of the bore, as shown in Fig. 2.

The inner end of the thimble 46 on the discharge side of the pump is subjected to pump pressure which exerts thereon an outward force proportional to pump pressure and creates a bearing pressure between the thimbles 48 and 50. The liquid discharged by the pump also acts upon the outer end of the thimble 48 and upon the shoulders formed by the elongated bores and exerts thereon an inward force proportional to pump pressure.

If it were not for the limit groove 54, the area of the thimble 48 upon which the liquid acts would be greater than the area of the inner end of the thimble 46 and the inward force exerted by this liquid would be greater than the outward force exerted thereby. Consequently, the thimble 48 would be moved out of contact with the flange of the thimble 50.

However, the limit groove 54 limits the area of the end of the thimble upon which the liquid may act and thereby limits the inward force exerted by the liquid, and it is so positioned relative to the bore of the thimble 48 that the outward force exceeds the inward force by just the amount required to produce an adequate seal between the thimbles 48 and 50 without creating excessive bearing pressures therebetween.

The bearing surface on the flange of the thimble 50 is intended to be arranged in a plane at right angles to the axis of the counterbore 49, but, since manufacturing errors are apt to occur which would cause it to lie in a different plane and thereby cause the thimble 48 to be cramped in the counterbore 49, the oil-tight spherical joint 51 is provided to compensate for such errors.

If the manufacturing errors are avoided or kept within close limits, the thimble 46 may be omitted and the thimble 48 replaced by a packing ring 48a as shown in Fig. 2A. The packing ring 48a would be initially urged against the flange of the thimble 50 or against the bearing surface 50a by springs 52a.

When the pump is delivering liquid through one of the sliding joints at a relatively high pressure, liquid seeps through the spherical joint 51 and between the thimble 46 and the bore 47 of that joint and enters the counterbore 49. It then flows through the duct 56 and floods the counterbore 49 on the intake side of the pump.

When the pump is operating in a circuit in which an insufficient volume is returned to the pump, the pistons must draw additional liquid from the reservoir 8 and thereby create a negative pressure in the sliding joint on the intake side of the pump. This negative pressure would tend to cause air to be drawn into the pump through the spherical joint 51 and between the thimble 46 and the wall of the bore 47 if the counterbore 49 were not filled with liquid.

When the pump is in operation, the pistons on the high pressure side of the pintle axis are forced progressively inward by the thrust member 5 and expel liquid from their cylinders through the cylinder and pintle ports. The pumping force imparted to each piston by the thrust member 5 is transmitted through that piston and the liquid in its cylinder to the pintle, the liquid in the cylinder transmitting a part of the pumping force direct to the pintle through the open ports and the remainder through the bearing surface on the cylinder barrel. The effect of the pumping forces transmitted through all of the pistons on the high pressure side of the pintle axis is to impress upon the pintle a resultant force (designated PR in Fig. 10) which tends to force the pintle and the pintle block toward the opposite side of the pump casing.

However, the sliding joint A on the low pressure side of the pintle axis is connected to the pintle port on the high pressure side of the pintle axis and arranged at an angle to the pintle axis so that the pressure of the liquid flowing through that joint exerts a force upon the pintle block at an angle to the piston axes. The vertical component of this force is equal and opposite in direction to the vertical resultant of the pumping forces, thus hydrostatically balancing the pintle.

For the purpose of illustration, a force diagram is shown in Fig. 10 in which it is assumed that the vertical resultant PR of the pumping forces is 6000#. The diagram shows the direction and location of all important forces which act upon the pintle assembly, the forces which act upon the horizontal guide faces 36 and 37 being omitted for the reason that the same are negligible as previously pointed out.

Under the conditions illustrated in Fig. 10, the pintle block assembly constitutes a rigid body in equilibrium under the action of the following four forces:

Vertical pumping force PR,—
Direction known
Location known
Magnitude known
Inclined hydrostatic force RL,—
Direction known
Location known
Magnitude unknown
Upper horizontal guide force L_2,—
Direction known
Location known
Magnitude unknown
Lower horizontal guide force L_3,—
Direction known
Location known
Magnitude unknown

When a rigid body is in equilibrium under the action of four forces, the resultant of any two of those forces must be equal and opposite to the resultant of the other two forces and must coincide with that resultant. In this case, the inclined hydrostatic supporting force RL of approximately 8800# is chosen and made to intersect the given vertical pumping force PR at a point R which will give favorable horizontal guide reactions.

The choice of this point R combined with the given magnitude and direction of the pumping force PR determines both the magnitude and the direction of the resultant PL of these two forces, which is approximately 6500# for a pumping force PR of 6000# and which passes through the point R. This determines the location, direction, and magnitude of the force L_1 which is the resultant of the two actual guide forces L_2 and L_3. As all these forces are horizontal and the locations of all are known, the inverse proportion between the distances L_1—L_2 and L_1—L_3 determines the division of the resultant horizontal force L_1, placing 5050# at L_2 on the upper guide **34** and 1450# at L_3 on the lower guide **35**.

The horizontal component P—L is centered about the line L_1 and creates a high bearing pressure between the rear face of the pintle guide **34** and the bearing face **39** on the pintle block. When the pump delivers liquid in the opposite direction, a high bearing pressure is created between the rear face of the guide **35** and the bearing face **40** on the pintle block.

When the pump is delivering liquid at high pressure, the bearing pressure between the pintle block and the pintle guide on the high pressure side of the pump may become so great that excessive friction or undue wear may result when the pintle block is shifted along the guides to vary pump displacement.

In order to relieve the vertical bearing faces of high bearing pressure in either direction of pump delivery, the pintle block **38** is provided, as shown in Figs. 1 and 4, with two pressure chambers **58** and **59** which extend inward from the bearing faces **39** and **40**, respectively, and have a packing ring **60** fitted in each in contact with the rear face of the adjacent pintle guide.

The chamber **58** is connected at the rear of its ring **60** to the main passage **44** by a duct **61**, and the chamber **59** is connected at the rear of its ring **60** to the main passage **45** by a duct **62**.

When the pump is delivering liquid through the passages **18** and **44**, the liquid in the duct **61** and the pressure chamber **58** is subjected to pump pressure which tends to move the face **39** out of contact with the rear face of the guide **34** and at the same time presses the packing ring **60** against the rear face of the guide **39** to prevent liquid from escaping from the chamber **58**.

In order to relieve the bearing face **39** from the greater part of this high bearing force and to permit the pintle block to be readily and easily moved along the guides **34** and **35**, the pressure chamber **58** is made with sufficient cross-sectional area to enable the liquid therein to react upon the pintle block with a force of sufficient magnitude to reduce the bearing pressure between the pintle block and the pintle guide to a value which is not great enough to impede the movement of the pintle block along the guides or to cause undue wear thereof. In the example given, the chamber **58** is sufficiently large to enable the liquid therein to exert a force of 3600# when the force PR is 6000# at which time the force L_2 is 5050#, thereby reducing the bearing force on the face **39** to 1450# and permitting the pintle block to be shifted easily and without wear of the contacting surfaces.

Since the bearing force on the bearing face **40** is only 1450#, it is not necessary to create pressure in the pressure chamber **59**, which has the same cross-sectional area as the chamber **58** and is located at the same distance from the pintle axis but upon the opposite side thereof.

When the pump is delivering liquid in the opposite direction, the conditions are exactly reversed, that is, the pumping forces act upwardly upon the pintle, the pintle is hydrostatically balanced by the vertical component of the force exerted upon the pintle block by the liquid flowing through the sliding joint A^2 the liquid in the pressure chamber **59** is under pump pressure, and the liquid in the pressure chamber **58** is under little if any pressure.

The pintle block **38** may be manually moved along the guides **34** and **35** to change the stroke of the pump, but it is ordinarily moved by liquid supplied from a gear pump (Figs. 1 and 7) which is arranged in the front head **9** and has its driving gear **63** fixed on the shaft **7** and its driven gear **64** journaled upon a stub shaft **65** fixed in the front head **9**.

The gears **63** and **64** are closely fitted for rotation, respectively, within two gear chambers **66** and **67** which are formed in the front head **9** and open into an intake chamber **68** and an exhaust chamber **69**. The chambers **66**, **67**, **68** and **69** are closed at the rear thereof by a plate **70** which is attached to the front head **9** and forms therewith a casing for the gear pump.

Leakage from the gear pump lubricates the bearing **11** and also seeps into a recess **71** which is formed in the front head **9** and extends above the gear **63** so that the gear pump chambers are kept filled with liquid.

Liquid in the recess **71** above a given level may flow through an orifice **72** into an annular drain channel **73** which is formed in the plate **70** and connected at its bottom by a duct **74** to a drain pipe **75** which discharges into the reservoir **8**.

The intake chamber **68** is connected by a radial duct **76** (Fig. 7) to a duct **77** which extends longitudinally of the casing **1** and communicates with a vertical suction pipe **78** extending downward into the reservoir **8** (Figs. 4 and 7).

The gear pump draws liquid through the pipe **78**, the ducts **77** and **76** and the intake chamber **68** and discharges it through the exhaust cham-

ber 69 and a radial duct 79 into a duct 80 which extends longitudinally of the casing 1 and communicates at one end with a duct 81 formed in the wall of a control cylinder 82 which is fastened to the side of the casing 1 in the plane of the pintle block 38. The other end of the duct 80 may communicate with a pipe 83 which is connected to the casing 1 and through which the gear pump may deliver liquid outside the casing 1 for control or other purposes.

The pressure of the liquid discharged by the gear pump is limited by a relief valve 84 and a resistance valve 85 which are connected in series (Fig. 9). The relief valve 84 (Fig. 7) has its plunger fitted in a bore 86 which is formed in the front head 9 in communication with the duct 79 and with an exhaust duct 87.

The plunger of the relief valve 84 is urged downward by a spring 88 to close communication between the ducts 79 and 87 and, when the pressure of the liquid in the duct 79 exceeds the resistance of the spring 88, the plunger rises and permits liquid to flow into the duct 87 which extends downward around the duct 80, as shown in Fig. 8, and then extends rearward (Fig. 6) to a port 89 formed in the bottom of the casing 1.

Liquid discharged by the gear pump through the relief valve 84 into the duct 87 maintains the return side of the variable delivery pump circuit under pressure and makes up for leakage losses, as will be presently explained.

The port 89 communicates with the open upper end of a valve casing 90 which is attached to the bottom of the casing 1 and closed thereby, as shown in Fig. 4.

The valve casing 90 contains the resistance valve 85 and a check valve 91 which is connected in parallel therewith between the port 89 and a pipe 92 which extends downward into the reservoir 8.

The check valve 91 permits liquid to be drawn freely from the reservoir 8 into the port 89 but forces liquid exhausted into the reservoir to pass through the resistance valve 85 which limits the pressure of the liquid in the duct 87.

The resistance valve 85 is thus connected in series with the relief valve 84 to permit the gear pump to deliver liquid to the control cylinder 82 at a pressure higher than the pressure at which it delivers liquid to the intake of the variable delivery pump.

The variable delivery pump is ordinarily employed in a closed circuit in which liquid is returned from the circuit direct to the pump intake. When the pump is operating a motor having a differential piston, the volume of liquid returned to the pump intake is either greater or less than the volume delivered by the pump, depending upon the direction of motor actuation.

In order to permit excess liquid to flow in either direction between the pump intake and the reservoir 8 and the gear pump to supply liquid to the pump intake when the pump is delivering liquid through either the pipe 14 or the pipe 15, the rear head 10 is provided with a transverse bore 93 (Fig. 5) having a plunger 94 fitted therein to control communication between three annular ports 95, 96 and 97 formed in the wall of the bore.

The port 95 is connected by a passage 98 to the main passage 12 in the rear head 10, the port 96 is connected by a passage 99 to the main passage 13, and the port 97 is connected by a passage 100 to a passage 101 which extends forward into the wall of the casing 1 and communicates with the duct 87 and the port 89.

The plunger 94 is provided upon one of its ends with a piston 102 having an annular groove 103 formed in its periphery and a radial duct 104 extending inward from the groove 103 to an axial duct 105 which extends inward from the end of the plunger and opens into the bore 93. The plunger 94 is provided at its other end with a similar piston 106 having a peripheral groove 107, a radial duct 108 and an axial duct 109.

When the pump is adjusted to deliver liquid to the pipe 14 and receive liquid from the circuit through the pipe 15, pressure will extend from the passage 12 through the passage 98, the port 95 and the ducts 104 and 105 to the left end of the bore 93 and move the plunger 94 to the position shown in Fig. 5. The gear pump will keep the return side of the circuit flooded with liquid delivered through the relief valve 84, the duct 87, the passages 101 and 100, the port 97, the bore 93 and the passageway 99 to the passageway 13, and the pressure of the liquid in the return side of the circuit will be determined by the adjustment of the resistance valve 85. If the total volume of liquid delivered to the pump intake from the circuit and by the gear pump is less than the volume required by the pump, liquid is drawn into the pump from the reservoir 8 through the pipe 92 and the check valve 91 and, if the volume returned from the circuit is greater than the volume required by the pump, the excess liquid is discharged into the reservoir through the resistance valve 85 and the pipe 92.

When the pump is adjusted to deliver liquid through the pipe 15 and receive liquid from the circuit through the pipe 14, pressure will extend from the passage 13 through the passage 99, the port 96 and the ducts 108 and 109 to the right end of the bore 93 and move the plunger 94 to the left in respect to Fig. 5 and thereby close communication between ports 96 and 97 and open communication between ports 95 and 97. The intake side of the pump is then open to the reservoir and the gear pump through the ports 95 and 97, and liquid may flow from the gear pump or the reservoir to the pump intake or excess liquid may be discharged into the reservoir from the return side of the circuit in the manner previously described.

The pressure of the liquid delivered by the pump in either direction is limited by one of two high pressure relief valves 110 and 111 which are exactly alike and extend through the bore 93 near the ends thereof to limit the movement of the plunger 94 in either direction.

Each of the relief valves 110 and 111 has a cylindrical casing 112 which extends through the bore 93 and is closely fitted in the rear head 10 both above and below the bore 93, lateral openings or admission ports 113 are formed in the side wall of the casing 112 to provide communication between the interior thereof and the bore 93, a discharge port 114 is formed in the lower end of the casing 112 to permit liquid to escape from the bore 93, a plunger 115 is closely fitted for reciprocation in the casing 112 above the admission ports 113, a valve 116 is arranged upon the lower end of the plunger 115 to engage a seat formed around the discharge port 114, and a spring (not shown) normally urges the plunger 115 downward to keep the discharge port 114 closed.

The discharge port 114 of the relief valve 110 communicates (Fig. 5) with a drain duct 117,

and the discharge port 114 of the relief valve 111 communicates with a drain duct 118 both of which are formed in the rear head 10 and extend downward therein. The drain ducts 117 and 118 (Figs. 4, 5 and 6) are connected, respectively, by drain ducts 119 and 120 to drain pipes 121 and 122 which discharge into the reservoir 8.

When the pump is delivering liquid through the passageway 12, pressure extends through the passage 98, port 95, bore 93 and ports 113 and acts upon the lower end of the relief valve plunger 115 and, when the pump pressure exceeds a predetermined maximum, the valve 116 is raised above its seat and liquid is exhausted through the port 114, ducts 117 and 119 and the drain pipe 121. When the pump is delivering liquid through the passage 13 and pump pressure exceeds the predetermined maximum, the relief valve 111 is operated and liquid is exhausted through the corresponding channels on that side of the pump.

It is sometimes desirable or necessary that the pump operate temporarily at zero stroke in order that one or more motors driven by the pump may remain stationary, but it is difficult to so adjust the pump that the axes of the pintle 2 and the driver 5 coincide with such precision that absolutely no liquid is discharged from the pump cylinders. Consequently, the pump is provided in each end of the bore 93 with a neutral bypass valve 123 through which very small volumes of liquid may pass freely to the reservoir 8.

Each bypass valve 123 is provided with a casing or valve body 124 which is closed at its outer end and closely fitted in the end of the bore 93 to close the same.

The valve body 124 has an axial bore 125 extending into it from its inner end and a recess 126 arranged near its outer end concentric with the bore 125 and connected by a lateral duct 127 to a branch of the high pressure relief valve drain duct, the valve body 124 on the left side of the pump in respect to Fig. 5 having its recess 126 connected to a branch of the duct 117 and the valve body 124 on the right side of the pump having its recess 126 connected to a branch of a duct 118.

The bore 125 has a helical compression spring 128 arranged therein around the reduced part of a valve plunger 129 which is fitted in the bore 125 and urged by the spring 128 toward the high pressure relief valve which limits the movement of the plunger. The spring 128 tends to keep the end of the reduced part of the plunger 129 out of contact with the entrance to the recess 126 with which it coacts to form a valve. The plunger 129 has formed therein a small discharge duct 130 which provides communication between the bore 93 and the bore 125.

When the pump is delivering a very small volume of liquid in one direction, the liquid flows through the bore 93 and one of the neutral bypass valves 123 via the duct 130, the bore 125, the recess 126 and the duct 127 and discharges into the relief valve drain passages but, as soon as the volume of liquid delivered by the pump exceeds the capacity of the duct 130 at a pressure determined by the resistance of the spring 128, pressure rises in the bore 93 and forces the plunger 129 against the entrance to the recess 126 and closes communication between the bore 93 and the drain passages so that the entire output of the pump is delivered into the pipe 14 or the pipe 15. When the pump is delivering a very small volume of liquid in the other direction, the liquid flows through the other neutral bypass valve 123 until the volume delivered by the pump exceeds the capacity of the duct 130 and then the valve 123 closes.

The volume of liquid delivered by the pump may be determined by the position of the pintle block 38 which is connected by a connecting rod 140 (Fig. 4) to the hollow stem 141 of a motor piston 142 which is closely fitted in the control cylinder 82 to reciprocate therein and has its stem 141 closely fitted in the ends thereof.

The connecting rod 140 is connected to the stem 141 by a universal joint 143 and has a drain channel 144 formed therein to provide communication between the interior of a pump casing 1 and a bore 145 which extends entirely through the piston 142 and its stem 141.

The piston 142 is provided intermediate its ends with a wide peripheral groove 146 which registers at all times with the duct 81 and communicates through a radial duct 147 with an annular port 148 formed in the wall of the bore 145.

The piston 142 has an annular port 149 formed in the wall of the bore 145 upon the outer side of the port 148 and connected by a duct 150 to the inner end of the control cylinder 82, and an annular port 151 formed in the wall of the bore 145 upon the inner side of the port 148 and connected by a duct 152 to the outer end of the control cylinder 82.

The bore 145 has a hollow valve 153 fitted therein and provided with two pistons which normally cover the ports 149 and 151 and prevent liquid from flowing therethrough from the port 148 which is always open to the gear pump through the duct 147, the groove 146 and the duct 81.

The valve 153 may be moved longitudinally of the bore 145 by a valve stem 154 which extends outward through the outer end of the cylinder 82 for connection to control mechanism or for manual operation.

When the valve 153 is moved outward, it will open the port 149 to the port 148 and the port 151 to the bore 145. Gear pump liquid may then flow through the port 149 and the duct 150 to the inner end of the cylinder 82 and move the piston 142 and the pintle block 38 to the left in respect to Fig. 4, and liquid will be ejected by the piston 142 from the outer end of the cylinder 82 through the duct 152, the port 151, the bore 145 and the drain channel 144.

The piston 142 starts to move as soon as the valve 153 uncovers the ports and it moves with the valve at substantially the same speed and through the same distance.

When the valve 153 is moved inward, it will open the port 151 to the port 148 and the port 148 to the bore 145. Gear pump liquid may then flow through the port 151 and the duct 152 to the outer end of the cylinder 82 and move the piston 142 and the pintle block 38 to the right in respect to Fig. 4, and liquid will be ejected by the piston 142 from the inner end of the cylinder 82 through the duct 150, the port 149, the interior of the hollow valve 153, the bore 145, the drain channel 144.

The volumetric delivery of the pump is determined by the distance the axis of the pintle is moved beyond the axis of the driver and it may be moved at any time regardless of pump pressure since the pintle is hydrostatically balanced.

The pressure created by the pump tends to force the cylinder barrel 3 toward the small end of the pintle 2 but is prevented from doing so by

fluid pressure in a pressure chamber 155 (Fig. 1) which is formed by a cylinder 156 arranged upon the end of the cylinder barrel and a piston 157 fixed upon the end of the pintle.

Liquid which leaks from between the cylinder barrel and the pintle seeps into the pressure chamber 155 and escapes therefrom through a duct 158 formed in the pintle. The escape of liquid through the duct 158 is controlled by mechanism (not shown) which regulates the rate of escape.

If the leakage from between the cylinder barrel and the pintle increases due to an increase in pump pressure, the pressure in the chamber 155 increases and urges the cylinder barrel toward the large end of the pintle taper and thereby decreases the leakage.

This mechanism maintains the slip of the pump substantially constant at all pump pressures but has not been illustrated nor described in detail herein as it constitutes a separate invention and is fully disclosed and claimed in a separate application.

The hydraulic machine herein set forth is susceptible of various modifications without departing from the scope of the invention as defined by the following claims which for descriptive purposes refer to the machine as a pump and to the pumping functions of certain parts but such terms are descriptive only and are not limitations to the claims which are equally applicable to a hydraulic motor.

The invention is hereby claimed as follows:

1. In a pump having a pintle, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the axis of said pintle and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of a pintle block fixed to said pintle at one end thereof to support the same and movable radially of said thrust member to vary pump displacement, and means arranged upon the intake side of the pintle axis for causing the liquid discharged from the cylinders on the discharge side of said axis to react upon said pintle block upon the intake side of said axis and tend to hydrostatically balance said pintle against said pumping force.

2. In a pump having a pintle, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the axis of said pintle and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of a pintle block fixed to said pintle at one end thereof to support the same and movable radially of said thrust member to vary pump displacement, and means arranged upon the intake side of the pintle axis for causing the liquid discharged from the cylinders on the discharge side of said axis to react upon said pintle block upon the intake side of said axis and at an oblique angle to said axis with a force having a component parallel and opposite to said pumping force and tending to hydrostatically balance said pintle against said pumping force.

3. In a pump having a pintle, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the axis of said pintle and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, and means for shifting said pintle to cause said pistons to expel liquid from said cylinders upon either one or the other side of said pintle axis to thereby enable said pump to deliver liquid in either direction, the combination with said pintle of a pintle block fixed to said pintle at one end thereof to support the same, and means arranged upon each side of the pintle axis for causing the liquid discharged from the cylinders on the discharge side of said axis to react upon said pintle block upon the intake side of said axis in either direction of pump delivery and tend to hydrostatically balance said pintle against said pumping force.

4. In a pump having a pintle, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the axis of said pintle and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, and means for shifting said pintle to cause said pistons to expel liquid from said cylinders upon either one or the other side of said pintle axis to thereby enable said pump to deliver liquid in either direction, the combination with said pintle of a pintle block fixed to said pintle at one end thereof to support the same, and means arranged upon each side of the pintle axis for causing the liquid discharged from the cylinders on the discharge side of said axis to react upon said pintle block upon the intake side of said axis in either direction of pump delivery and at an oblique angle to said axis with a force having a component parallel and opposite to said pumping force and tending to hydrostatically balance said pintle against said pumping force.

5. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through

said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at one end thereof to support the same and slidable upon said guides to vary pump displacement, and means arranged upon the intake side of the pintle axis for causing liquid discharged from the cylinders on the discharge side of said axis to react upon said pintle block upon the intake side of said axis and tend to hydrostatically balance said pintle against said pumping force.

6. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at one end thereof to support the same and slidable upon said guides to vary pump displacement, means for causing liquid discharged from the cylinders on the discharge side of the pump to react upon said pintle block upon the intake side of said pintle axis and tend to hydrostatically balance said pintle against said pumping force, and shoulders arranged upon said pintle block between said guides and in engagement with the opposed faces thereof to support said pintle block during non-operating periods and to positively retain said pintle in position against the action of unbalanced radial forces during operating periods.

7. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at one end thereof to support the same and slidable upon said guides to vary pump displacement and to change the direction of pump delivery, and means arranged upon each side of the pintle axis for causing liquid discharged from the cylinders on the discharge side of said axis in either direction of pump delivery to react upon said said pintle block upon the intake side of said axis and tend to hydrostatically balance said pintle against said pumping force.

8. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at one end thereof to support the same and slidable upon said guides to vary pump displacement, and means arranged upon the intake side of said piston axis for causing liquid discharged from the cylinders on the discharge side of said axis to react upon said pintle block upon the intake side of said axis and at an oblique angle to said axis with a force having a component parallel and opposite to said pumping force and tending to hydrostatically balance said pintle against said pumping force.

9. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at one end thereof to support the same and slidable upon said guides to vary pump displacement and to change the direction of pump delivery, and means arranged upon each side of the pintle axis for causing liquid discharged from the cylinders on the discharge side of said axis in either direction of pump delivery to react upon said pintle block upon the intake side of said axis and at an oblique angle to said axis with a force having a component parallel and opposite to said pumping force and tending to hydrostatically balance said pintle against said pumping force.

10. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at on end thereof to support the same and slidable upon said guides to vary pump displacement, means for causing liquid discharged from the cylinders on the discharge side of the pump to react upon said pintle block upon the intake side of said pintle axis and at an oblique angle to

said axis with a force having one component parallel and opposite to said pumping force and tending to hydrostatically balance said pintle against said pumping force and another component parallel to the axis of said pintle and creating at high pump pressure a high bearing pressure between said pintle block and pintle guide in an axial direction, and means for reducing said bearing pressure including a pressure chamber open to pump pressure and arranged betwen said pintle block and one of said guides.

11. In a pump having a casing, a pintle arranged within said casing longitudinally thereof, a cylinder barrel journaled upon said pintle to rotate thereon and provided with cylinders to receive liquid at one side of the axis of said pintle and to discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for urging each piston on the discharge side of said axis into its cylinder to expel liquid therefrom and thereby transmitting through said piston a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides fixed in said casing transverse to said pintle axis, a pintle block fixed to said pintle at one end thereof to support the same and slidable upon said guides to vary pump displacement and to change the direction of pump delivery, means for causing liquid discharged from the cylinders on the discharge side of the pump in either direction of pump delivery to react upon said pintle block upon the intake side of said pintle axis and at an oblique angle to said axis with a force having one component parallel and opposite to said pumping force and tending to hydrostatically balance said pintle against said pumping force and another component parallel to the axis of said pintle and creating at high pump pressure a high bearing pressure between said pintle block and pintle guide in an axial direction, and means for reducing said bearing pressure in either direction of pump delivery including a pressure chamber open to pump pressure and arranged between said pintle block and one of said guides.

12. A pump, comprising a casing having two fluid channels formed in its rear end wall for connection to an external circuit, an upper and a lower pintle guide fixed in said casing and extending transversely thereof, a pintle extending longitudinally of said casing between said guides and provided with an upper port and passage and a lower port and passage, a cylinder barrel arranged in front of said guides and fitted upon said pintle to rotate thereon and provided with cylinders to communicate with said pintle ports alternately as said cylinder barrel rotates, a piston arranged in each cylinder to reciprocate therein and eject liquid therefrom into the pintle port and passage on the discharge side of the pump and to permit liquid to enter its cylinder through the pintle port and passage on the intake side of the pump, a thrust member arranged around said cylinder barrel eccentric to said pintle for transmitting to said pistons during one part of a revolution of said cylinder barrel pumping forces which tend to move said pintle toward the intake side of the pump, a pintle block fixed to said pintle upon the rear end thereof to support the same and engaging said guides upon the rear faces thereof, said pintle block being movable along said guides to vary pump displacement and provided with a fluid passage which connects the pintle passage on the discharge side of the pintle axis to a fluid channel formed in the end wall of the casing upon the intake side of the pintle axis to permit the liquid discharged from the cylinders to react upon the pintle block upon the intake side of the pintle axis and thereby hydrostatically balance said pintle against said pumping force, and means for connecting the other pintle passage to the other fluid channel in the end wall of the casing.

13. A pump, comprising a casing having an upper and a lower fluid channel formed in its rear end wall for connection to an external circuit, an upper and a lower pintle guide fixed in said casing and extending transversely thereof, a pintle extending longitudinally of said casing between said guides and provided with an upper port and passage and a lower port and passage, a cylinder barrel arranged in front of said guides and fitted upon said pintle to rotate thereon and provided with cylinders to communicate with said pintle ports alternately as said cylinder barrel rotates, a piston arranged in each cylinder to reciprocate therein and eject liquid therefrom into the pintle port and passage on the discharge side of the pump and to permit liquid to enter its cylinder through the pintle port and passage on the intake side of the pump, a thrust member arranged around said cylinder barrel eccentric to said pintle for transmitting to said pistons during one part of a revolution of said cylinder barrel pumping forces which tend to move said pintle toward the intake side of the pump, and a pintle block fixed to said pintle upon the rear end thereof to support the same and engaging said guides upon the rear faces thereof, said pintle block being movable along said guides to vary pump displacement and provided with two fluid passages each of which connects the pintle passage on one side of the pintle axis to the fluid channel formed in the end wall of the casing upon the other side of the pintle axis to permit the liquid discharged from the cylinders on one side of the pintle axis to react upon the pintle block upon the other side of the pintle axis and thereby hydrostatically balance said pintle against said pumping forces.

14. A pump, comprising a casing having an upper and a lower fluid channel formed in its rear end wall for connection to an external circuit, an upper and a lower pintle guide fixed in said casing and extending transversely thereof, a pintle extending longitudinally of said casing between said guides and provided with an upper port and passage and a lower port and passage, a cylinder barrel arranged in front of said guides and fitted upon said pintle to rotate thereon and provided with cylinders to communicate with said pintle ports alternately as said cylinder barrel rotates, a piston arranged in each cylinder to reciprocate therein and eject liquid therefrom into the pintle port and passage on the discharge side of the pump and to permit liquid to enter its cylinder through the pintle port and passage on the intake side of the pump, a thrust member arranged around said cylinder barrel eccentric to said pintle for transmitting to said pistons during one part of a revolution of said cylinder barrel pumping forces which tend to move said pintle toward the intake side of the pump, a pintle block fixed to said pintle upon the rear end thereof to support the same and engaging said guides upon the rear faces thereof, said pintle

block being movable along said guides to vary pump displacement and provided with a fluid passage which connects the pintle passage on the discharge side of the pintle axis to a fluid channel formed in the end wall of the casing upon the intake side of the pintle axis to permit the liquid discharged from the cylinders to react upon the pintle block upon the intake side of the pintle axis and thereby hydrostatically balance said pintle against said pumping force, means for connecting the intake pintle passage to the other fluid channel, and a cylinder connected to said discharge passage and arranged in said pintle block upon the discharge side of the pintle axis to act upon a pintle guide and reduce the bearing pressure between that guide and said pintle block.

15. A pump, comprising a casing having an upper and a lower fluid channel formed in its rear end wall for connection to an external circuit, an upper and a lower pintle guide fixed in said casing and extending transversely thereof, a pintle extending longitudinally of said casing between said guides and provided with an upper port and passage and a lower port and passage, a cylinder barrel arranged in front of said guides and fitted upon said pintle to rotate thereon and provided with cylinders to communicate with said pintle ports alternately as said cylinder barrel rotates, a piston arranged in each cylinder to reciprocate therein and eject liquid therefrom into the pintle port and passage on the discharge side of the pump and to permit liquid to enter its cylinder through the pintle port and passage on the intake side of the pump, a thrust member arranged around said cylinder barrel eccentric to said pintle for transmitting to said pistons during one part of a revolution of said cylinder barrel pumping forces which tend to move said pintle toward the intake side of the pump, a pintle block fixed to said pintle upon the rear end thereof to support the same and engaging said guides upon the rear faces thereof, said pintle block being movable along said guides to change pump displacement and the direction of pump delivery and provided with two fluid passages each of which connects the pintle passage on one side of the pintle axis to the fluid channel formed in the end wall of the casing upon the other side of the pintle axis to permit the liquid discharged from the cylinders on one side of the pintle axis to react upon the pintle block upon the other side of the pintle axis and thereby hydrostatically balance said pintle against said pumping force, and means for reducing the bearing pressure between said pintle block and said guides.

16. In a pump having a casing and a stationary member carried by said casing and provided with a fluid passage, the combination of a pintle guide spaced from said member and arranged in a stationary position within said casing and extending transversely thereof, a pintle having a supporting member fixed thereon between said guide and said member in engagement with said guide and provided with a fluid passage in registry with the passage in said stationary member, means for moving said pintle supporting member along said guide to vary pump displacement, a bearing surface arranged upon one of said members around the end of the passage therein, and an annular packing closely fitted in the end of the passage in the other member and having sufficient area exposed to the pressure therein to enable it to be urged by fluid pressure against said bearing surface with sufficient force to form a slidable and substantially fluid-tight joint between said passages.

17. In a pump having a casing and a stationary member carried by said casing and provided with a fluid passage, the combination of a pintle guide spaced from said member and arranged in a stationary position within said casing and extending transversely thereof, a pintle having a supporting member fixed thereon between said guide and said member in engagement with said guide and provided with a fluid passage in registry with the passage in said stationary member, means for moving said pintle supporting member along said guide to vary pump displacement, a bearing surface arranged upon one of said members around the end of the passage therein, a packing engaging said bearing surface and fitted in the end of the passage in the other member and having an opening therethrough of sufficient size to maintain communication between said passages in any position of said pintle supporting member, and a thimble forming universal liquid-tight joint with said packing to provide a self-alining joint between said members and having a sufficiently large area thereof subjected to fluid pressure to urge said packing against said bearing surface and thereby provide a substantially liquid-tight joint between said members.

18. In a pump having a casing provided with fluid channels in one end thereof, the combination of a pintle guide spaced from said end and arranged within said casing transversely thereof, a pintle having a pintle block fixed thereon between said guide and said end in engagement with said guide, said pintle block being provided with fluid passages each of which registers with one of said fluid channels, means for moving said pintle block along said guide to vary pump displacement, a stationary thimble fixed in the inner end of each fluid channel and forming a liquid-tight joint with said casing, and a movable thimble closely fitted in the outer end of each fluid passage and forming a fluid-tight joint with said pintle block and having a sufficiently large area thereof subjected to the pressure in said passage to enable it to be urged by fluid pressure against one of said stationary thimbles with sufficient force to form a substantially fluid-tight joint therewith and to keep said passage in communication with the corresponding channel in any position of said pintle block along said guide.

19. In a pump having a casing provided with fluid channels in one end thereof, the combination of a pintle guide arranged within said casing transversely thereof, a pintle having a pintle block engaging said guide and provided with fluid passages each of which registers with one of said fluid channels and has a counterbore at the outer end thereof, means for moving said pintle block along said guide to vary pump displacement, a stationary thimble fixed in the inner end of each fluid channel and forming a liquid-tight joint with said casing, a movable thimble closely fitted in the counterbore at outer end of each fluid passage and forming a fluid-tight joint with said pintle block and urged by fluid pressure against one of said stationary thimbles to form a fluid-tight joint therewith and to keep said passage in communication with the corresponding channel in any position of said pintle block along said guide, and means for keeping the counterbore around the thimble on the intake side of the pump flooded with liquid.

20. In a pump having a casing provided with fluid channels in one end thereof, the combination of a pintle guide spaced from said end and arranged within said casing transversely thereof, a pintle having a pintle block fixed thereon between said guide and said end in engagement with said guide, said pintle block being provided with fluid passages each of which registers with one of said fluid channels, means for moving said pintle block along said guide to vary pump displacement, a stationary thimble fixed in the inner end of each fluid channel and forming a liquid-tight joint with said casing, and a movable thimble closely fitted in the outer end of each fluid passage and forming a liquid-tight joint with said pintle block and having a sufficiently large area thereof subjected to the pressure in said passage to enable it to be urged by fluid pressure against one of said stationary thimbles with sufficient force to form a substantially liquid-tight joint therewith and to keep said passage in communication with the corresponding channel in any position of said pintle block along said guide.

21. In a pump provided with a pintle having intake and discharge passages formed therein upon opposite sides of the pintle axis, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the axis of said pintle and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, and a thrust member arranged around said pintle eccentric thereto for transmitting to each piston on the discharge side of said axis a pumping force which tends to move said pintle toward the intake side of the pump, the combination with said pintle of pintle guides arranged in a stationary position, a pintle block fixed to said pintle at one end thereof in engagement with said guides and movable along said guides to vary pump displacement, said pintle block being provided with two fluid channels each of which has one end thereof in communication with a pintle passage upon one side of the pintle axis and the other end thereof terminating upon the outside of said block upon the opposite side of said pintle axis, and an abutment arranged in a stationary position and provided with two fluid channels each of which registers with one of said pintle block channels to enable liquid discharged from said pump to react upon the walls of said channels and create a force which tends to counteract said pumping force.

22. In a pump provided with a pintle having intake and discharge passages formed therein upon opposite sides of the pintle axis, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the axis of said pintle and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, a thrust member arranged around said pintle eccentric thereto for transmitting to each piston on the discharge side of said axis a pumping force which tends to move said pintle toward the intake side of the pump, means for adjusting said pump to cause said pistons to expel liquid from said cylinders upon either one or the other side of said pintle axis to thereby enable said pump to deliver liquid in either direction, the combination with said pintle of pintle guides arranged in a stationary position, a pintle block fixed to said pintle at one end thereof in engagement with said guides and movable along said guides to vary pump displacement, said pintle block being provided with two fluid channels each of which has one end thereof in communication with a pintle passage upon one side of the pintle axis and the other end thereof terminating upon the outside of said block upon the opposite side of said pintle axis, and an abutment arranged in a stationary position and provided with two fluid channels each of which registers with one of said pintle block channels to enable liquid discharged from said pump to react upon the walls of said channels and create a force which tends to counteract said pumping force in either direction of pump delivery.

23. A pump, comprising a casing, an upper and a lower stationary pintle guide arranged in said casing transversely thereof, a pintle extending between said guides longitudinally of said casing and having intake and discharge passages formed therein upon opposite sides of the pintle axis, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the pintle axis and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, a thrust member arranged around said pintle eccentric thereto for transmitting to each piston on the discharge side of said axis a pumping force which tends to move said pintle toward the intake side of the pump, a pintle block arranged at the rear of said guides in contact therewith and fixed to said pintle at one end thereof, said pintle block being movable along said guides to vary pump displacement and provided with two fluid channels each of which has one end thereof in communication with a pintle passage upon one side of the pintle axis and the other end thereof terminating upon the outside of said block upon the opposite side of said pintle axis, and an abutment arranged behind said pintle block and provided with two fluid channels each of which registers with one of said pintle block channels to enable liquid discharged from said pump to react upon the walls of said channels and create a force which tends to counteract said pumping force.

24. A pump, comprising a casing, an upper and a lower stationary pintle guide arranged in said casing transversely thereof, a pintle extending between said guides longitudinally of said casing and having intake and discharge passages formed therein upon opposite sides of the pintle axis, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the pintle axis and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, a thrust member arranged around said pintle eccentric thereto for transmitting to each piston on the discharge side of said axis a pumping force which tends to move said pintle toward the intake side of the pump, a pintle block arranged at the rear of said guides in contact therewith and fixed to said pintle at one end thereof, said pintle block being movable along said guides to vary pump displacement and provided with two fluid channels each of which has one end thereof in communication with a pintle passage upon one side of the pintle axis and the other end thereof terminating upon the outside of said block upon the opposite side of said pintle

axis, and an abutment arranged behind said pintle block and provided with two fluid channels each of which registers with one of said pintle block channels to enable liquid discharged from said pump to react upon the walls of said channels and create a force which tends to counteract said pumping force, said channels being so arranged that the force created by fluid pressure therein acts at an oblique angle to the pintle axis.

25. A pump, comprising a casing, an upper and a lower stationary pintle guide arranged in said casing transversely thereof, a pintle extending between said guides longitudinally of said casing and having intake and discharge passages formed therein upon opposite sides of the pintle axis, a cylinder barrel provided with radial cylinders and fitted upon said pintle to rotate thereon to enable said cylinders to receive liquid at one side of the pintle axis and discharge liquid at the other side of said axis as said cylinder barrel rotates, a piston fitted in each cylinder, a thrust member arranged around said pintle eccentric thereto for transmitting to each piston on the discharge side of said axis a pumping force which tends to move said pintle toward the intake side of the pump, a pintle block arranged at the rear of said guides in contact therewith and fixed to said pintle at one end thereof, said pintle block being movable along said guides to vary pump displacement and provided with two fluid channels each of which has one end thereof in communication with a pintle passage upon one side of the pintle axis and the other end thereof terminating upon the outside of said block upon the opposite side of said pintle axis, an abutment arranged behind said pintle block and provided with two fluid channels each of which registers with one of said pintle block channels to enable liquid discharged from said pump to react upon the walls of said channels and create a force which tends to counteract said pumping force, and shoulders arranged upon said pintle block and engaging the opposed faces of said guides to restrain said pintle from radial movement.

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