March 13, 1956 W. FERRIS 2,737,894

AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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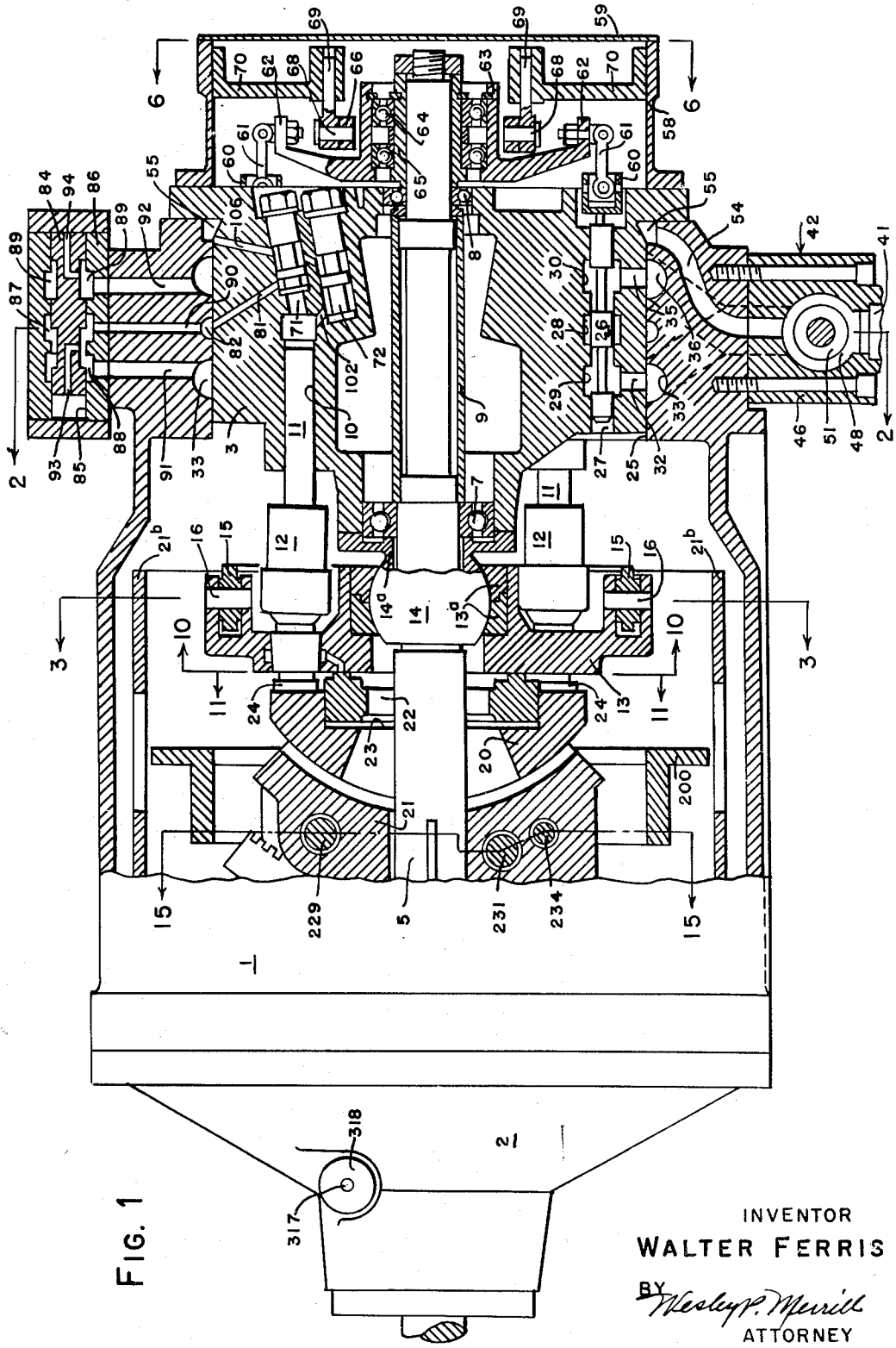


FIG. 1

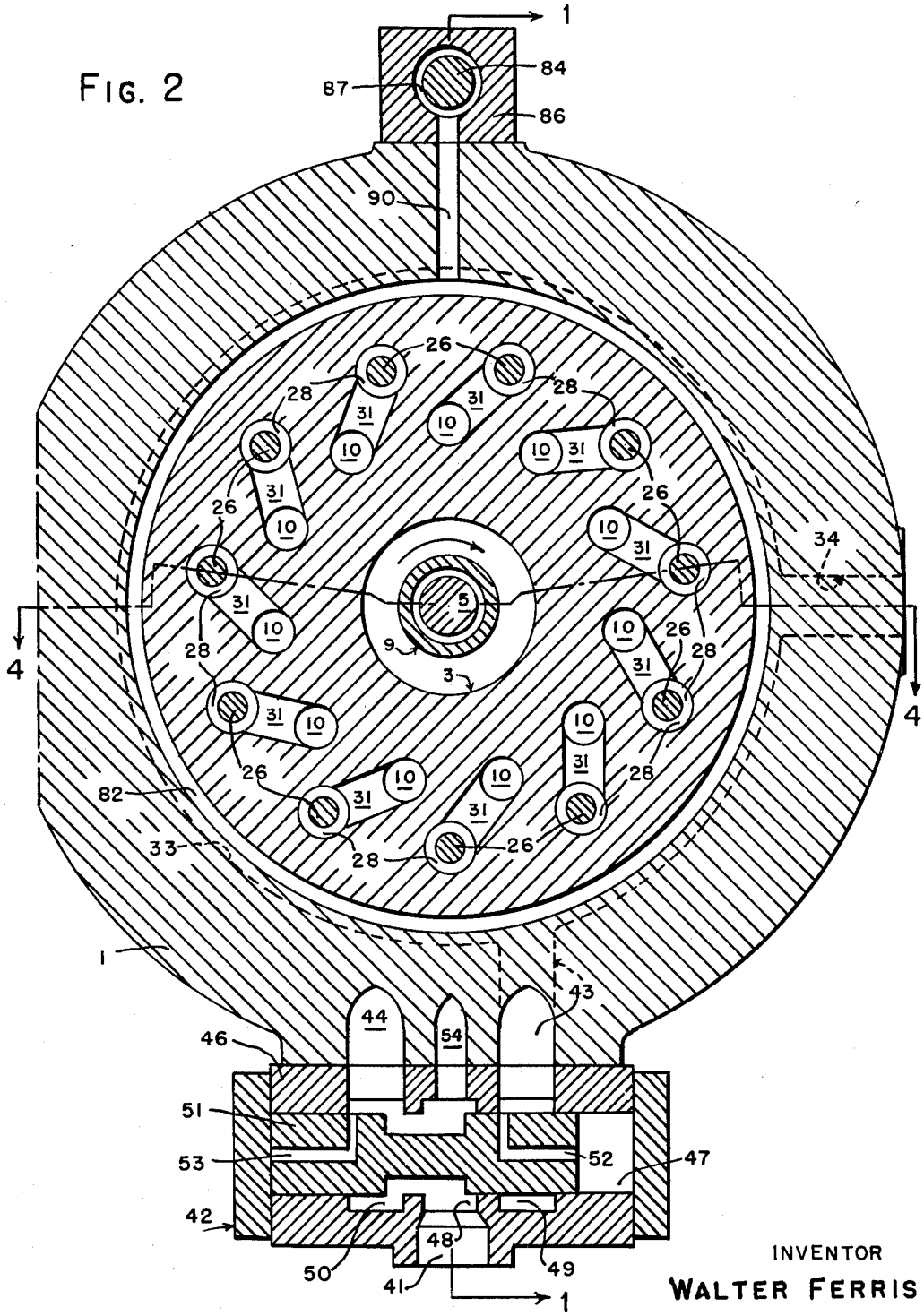
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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 2



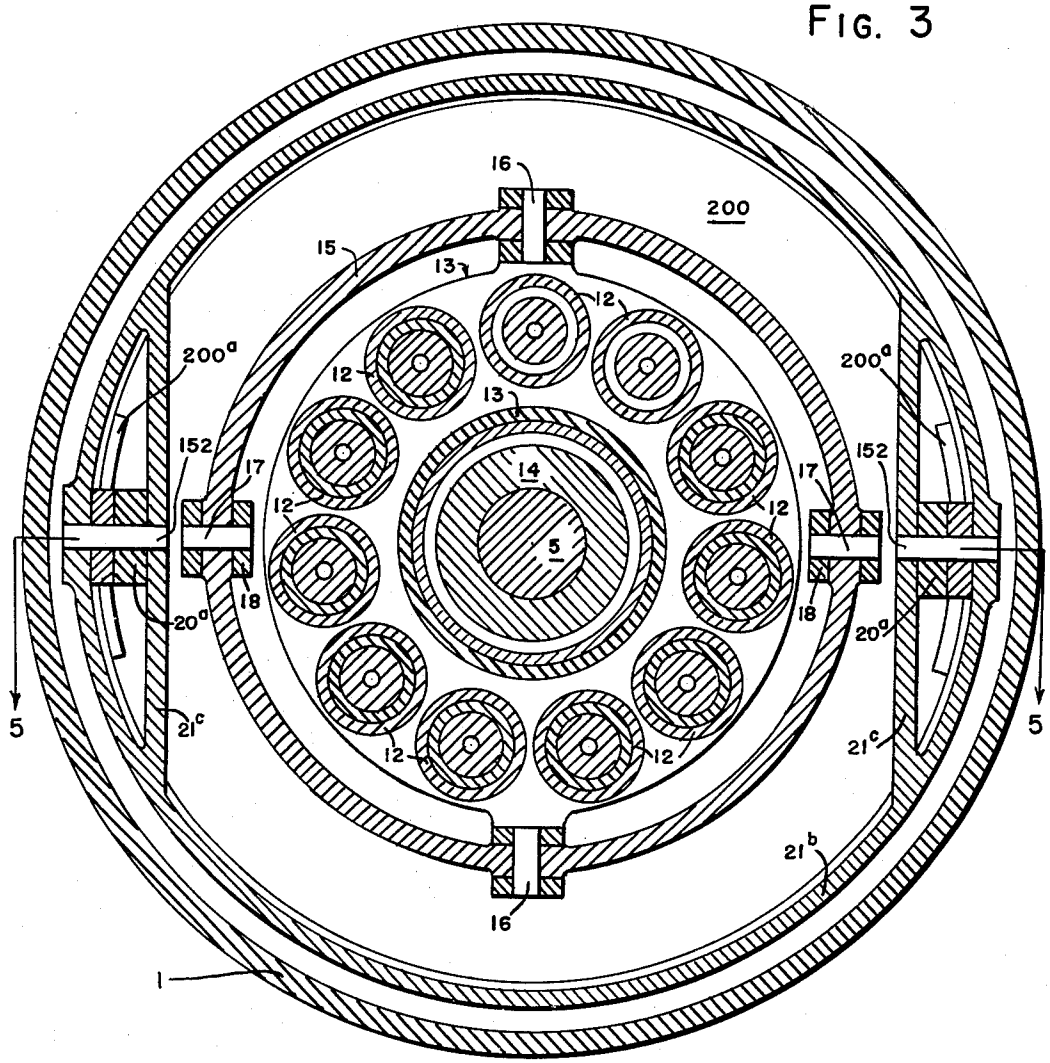

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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 3



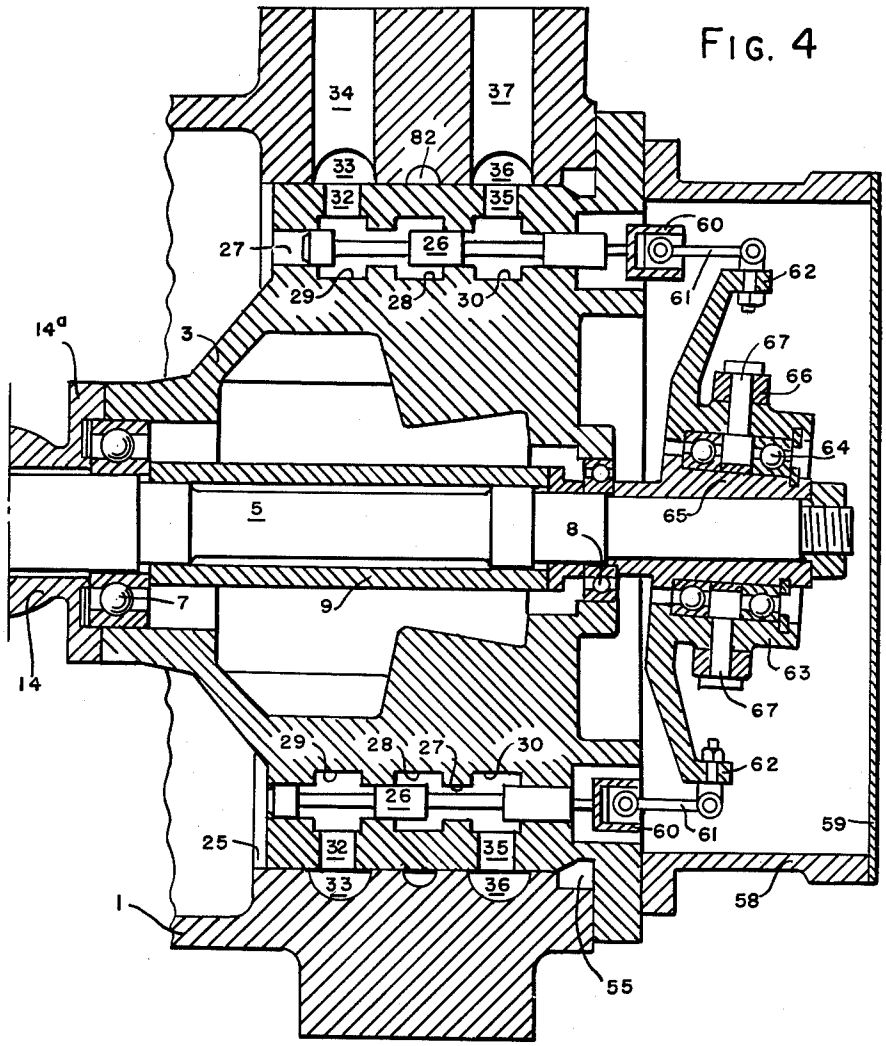

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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 4




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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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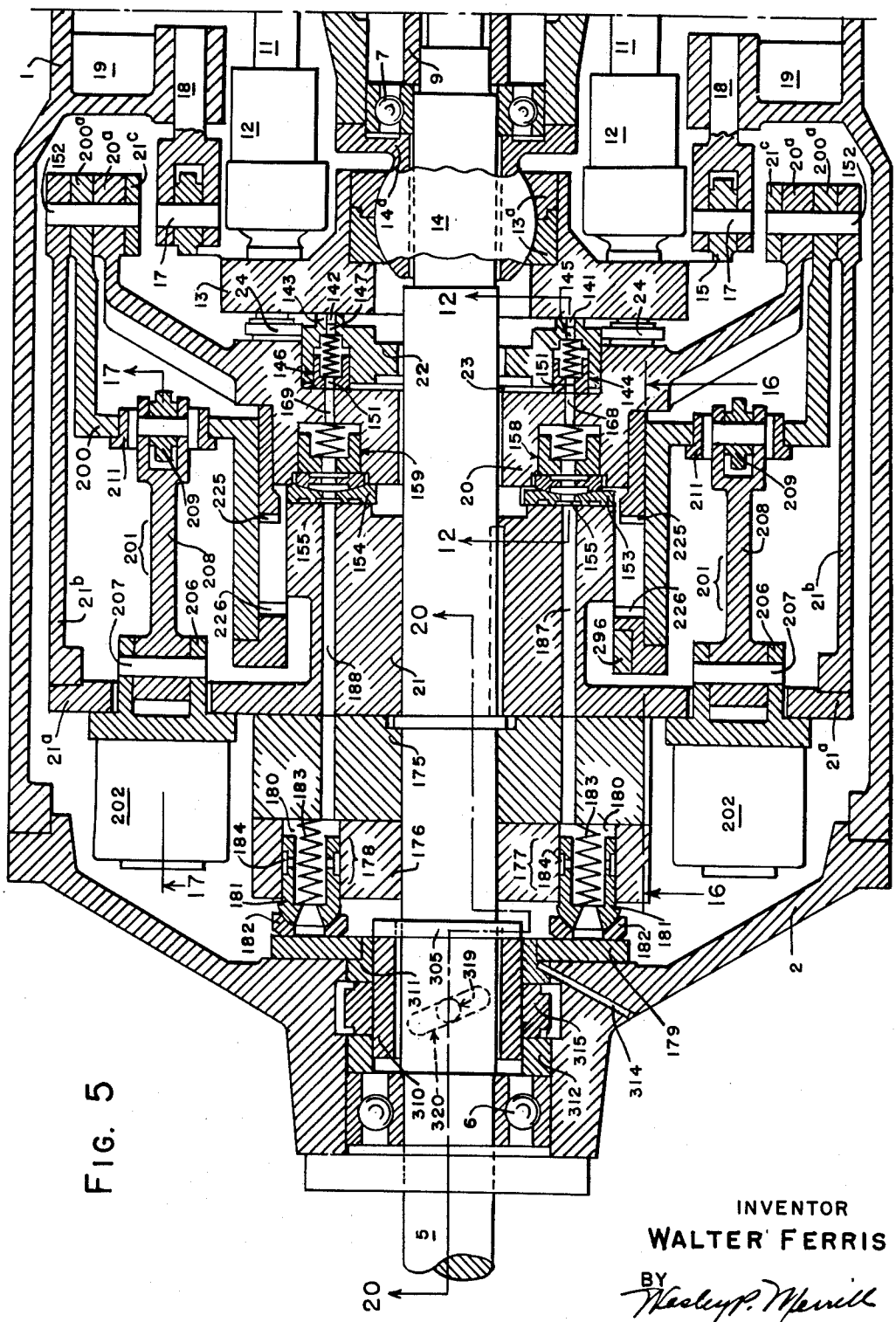


FIG. 5

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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 6

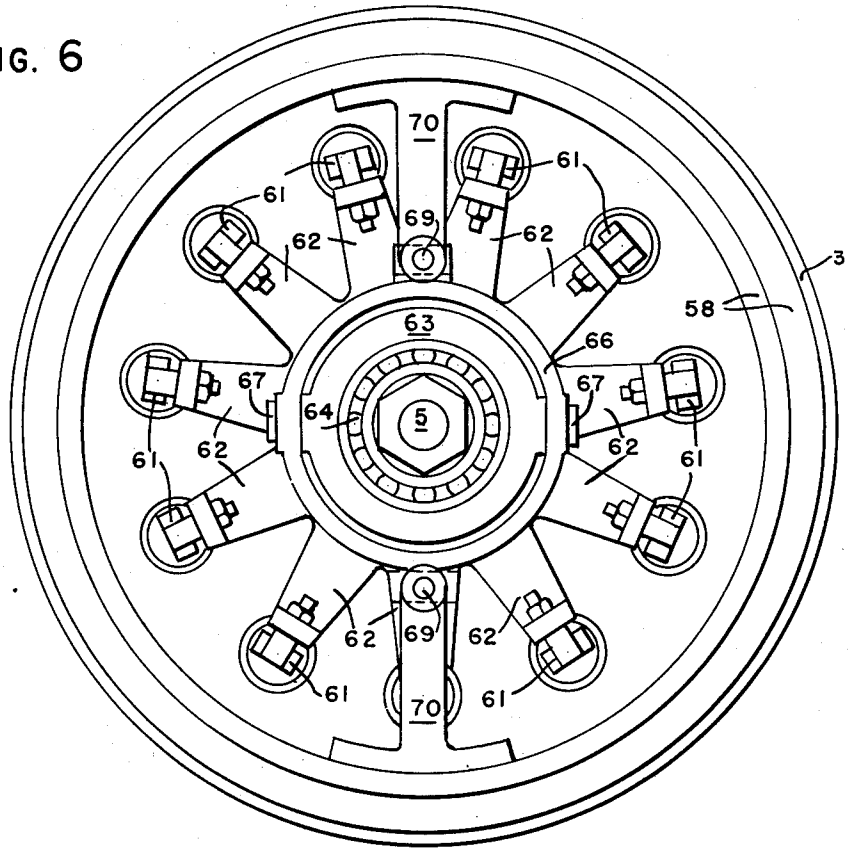
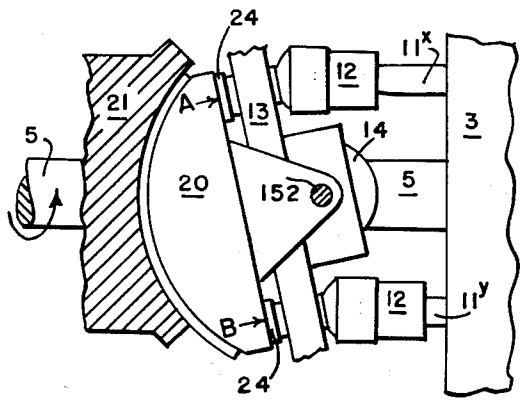



FIG. 25




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FIG. 7

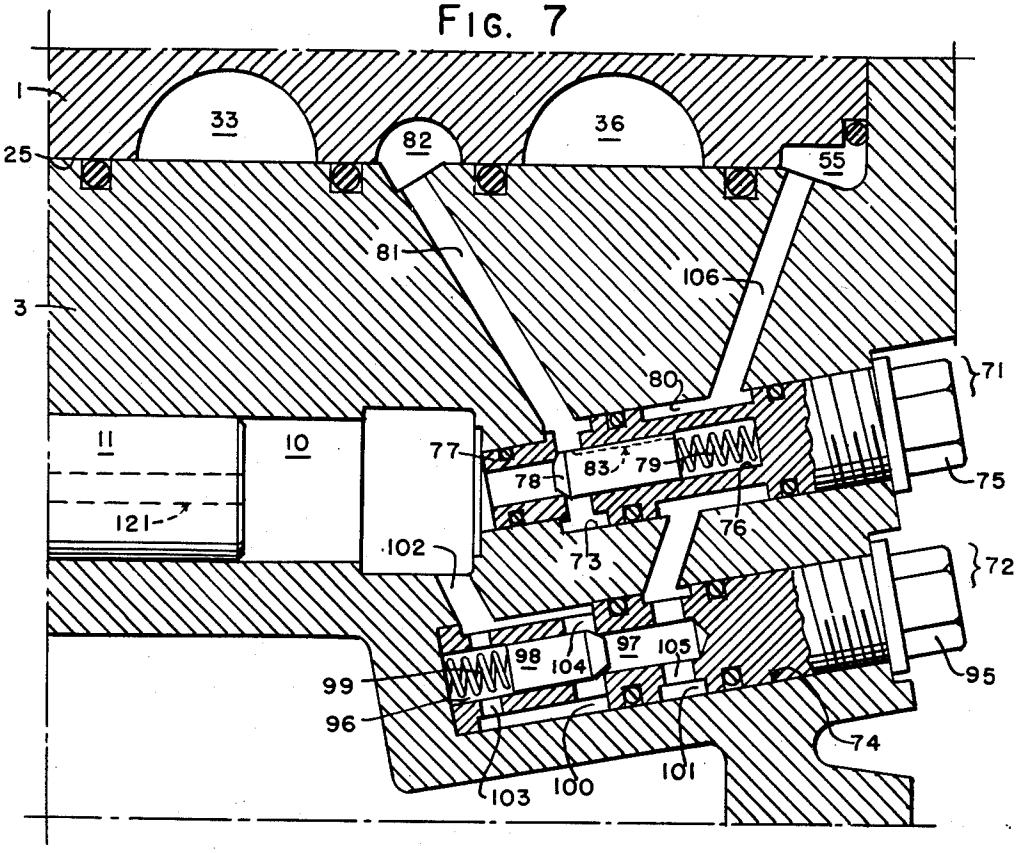
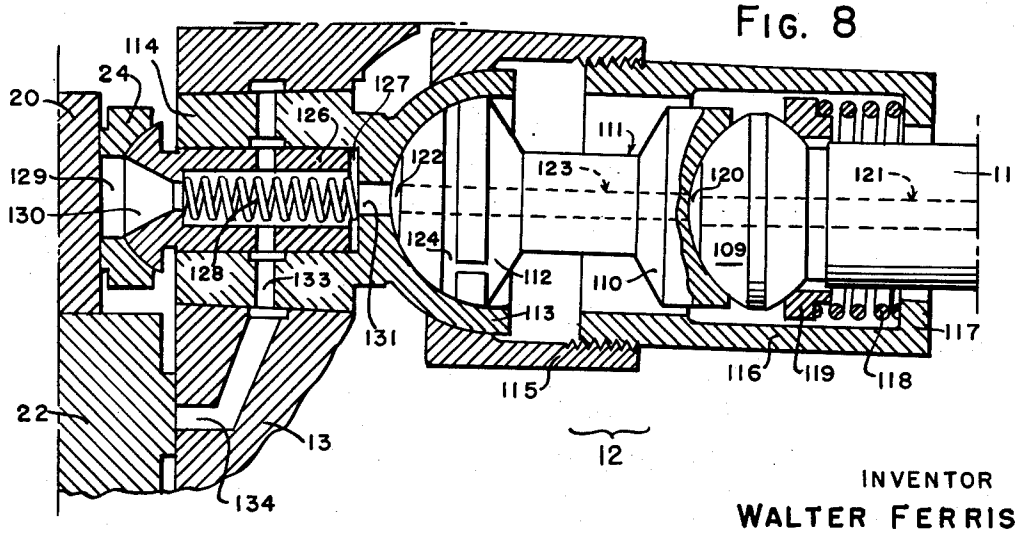



FIG. 8




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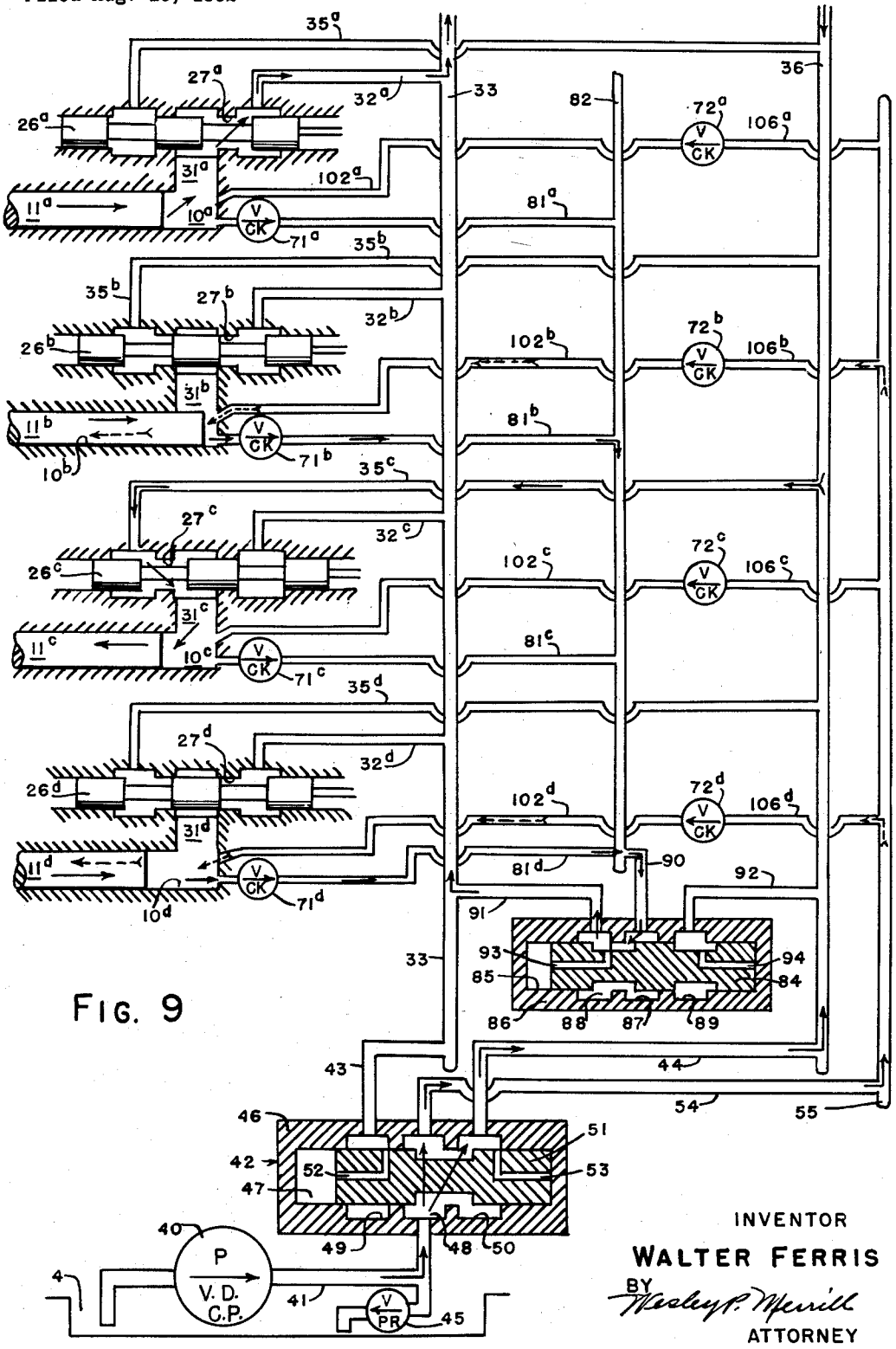



FIG. 9

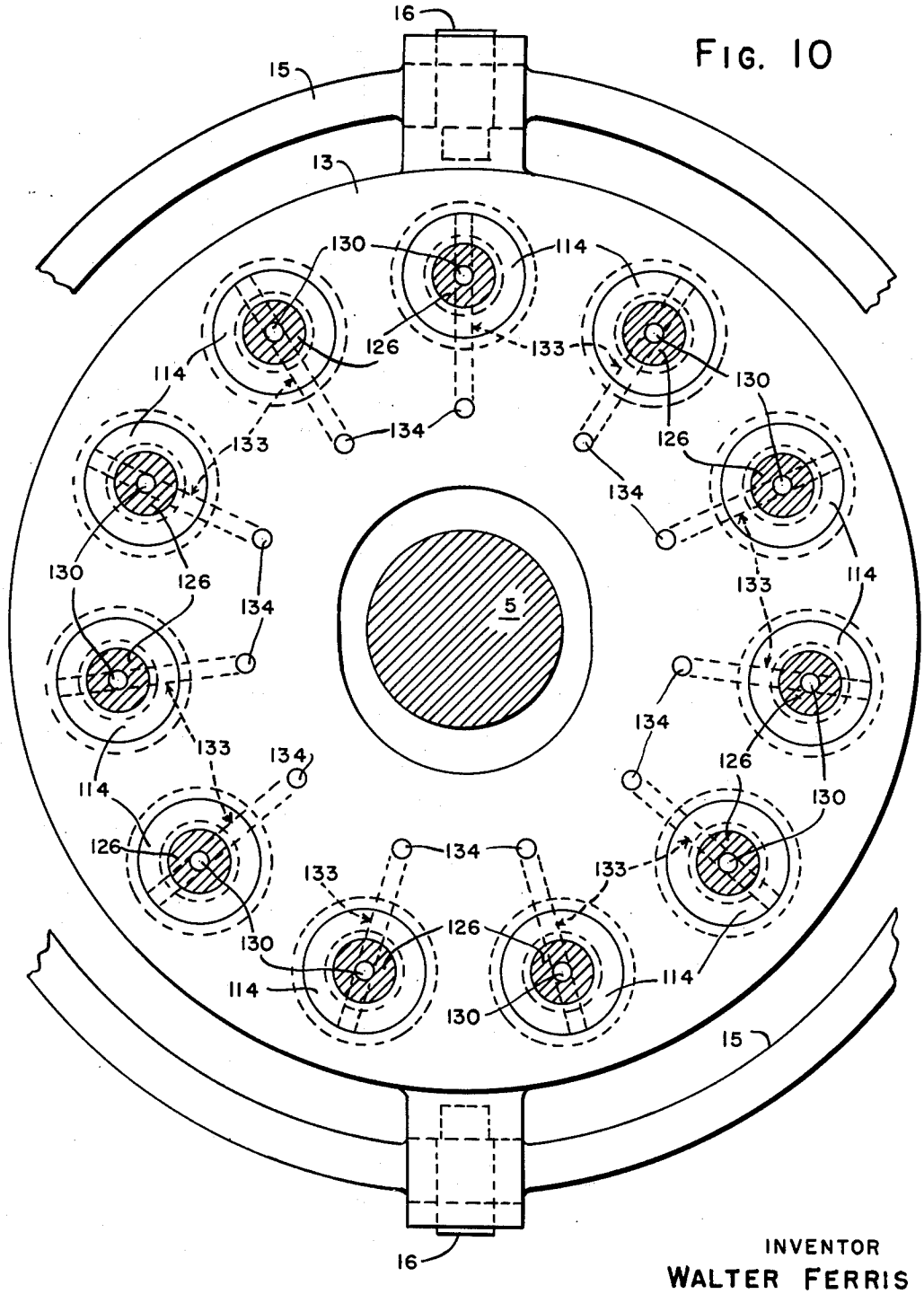
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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 10




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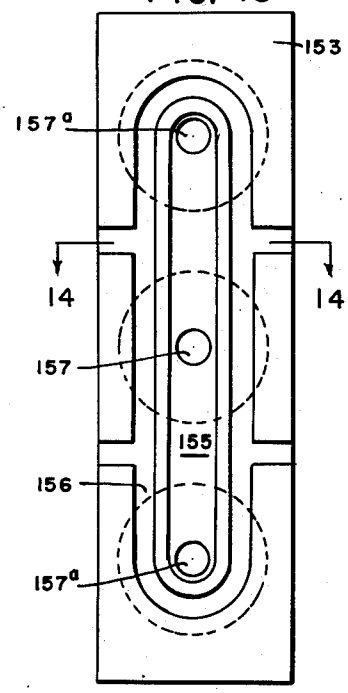
AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 14




FIG. 13



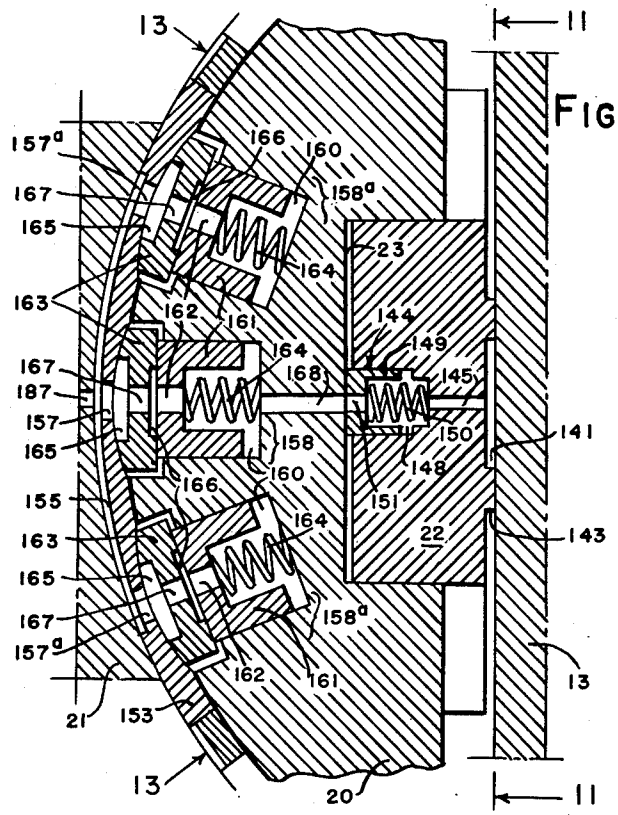




FIG. 12

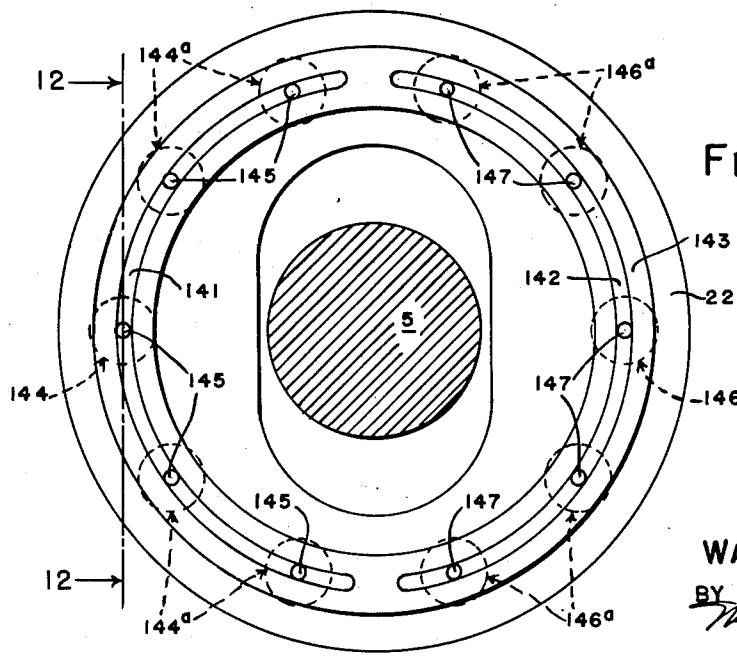



FIG. 11

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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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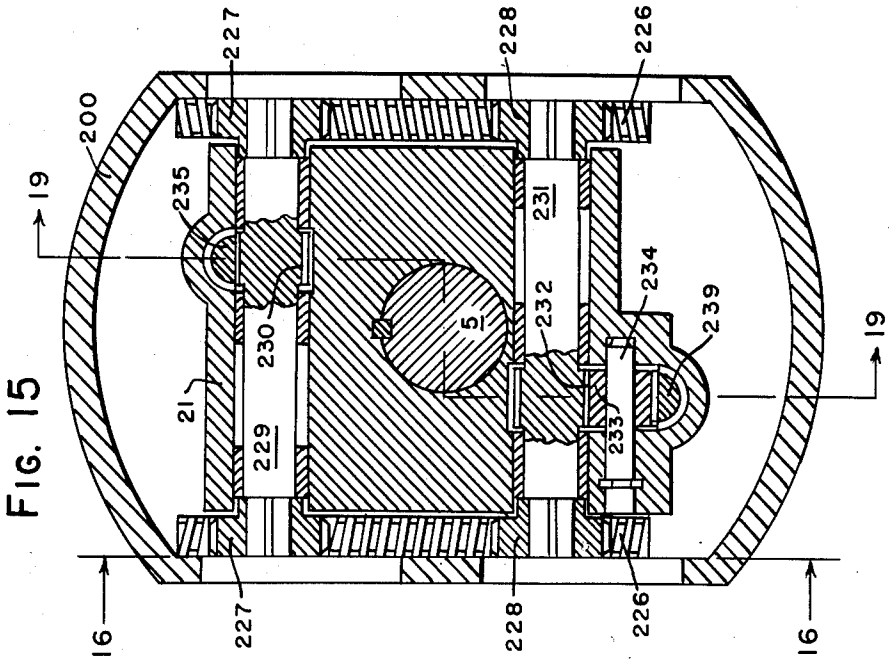



FIG. 15

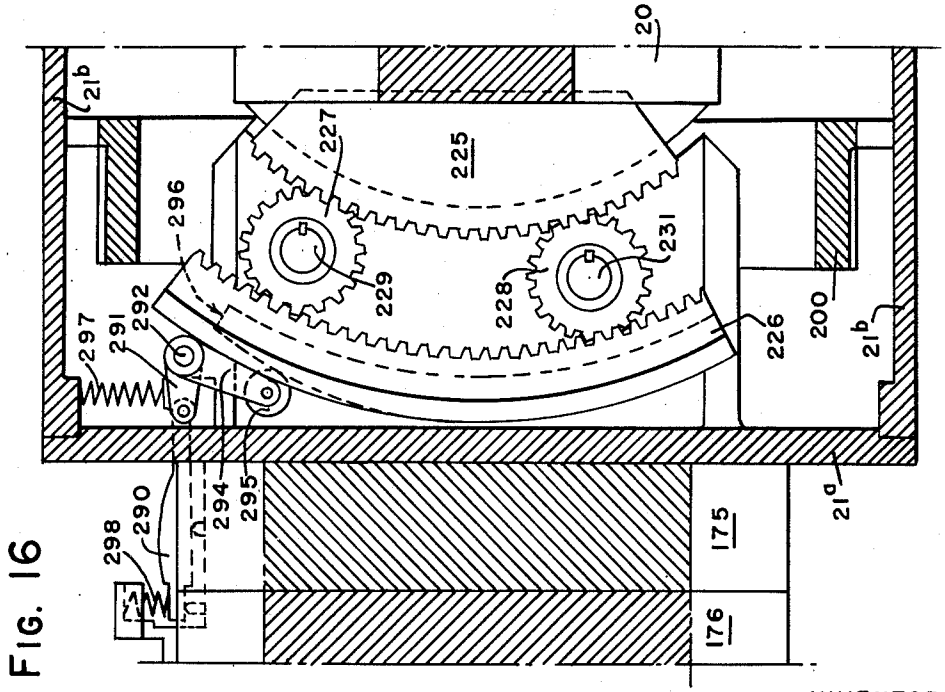



FIG. 16

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FIG. 17

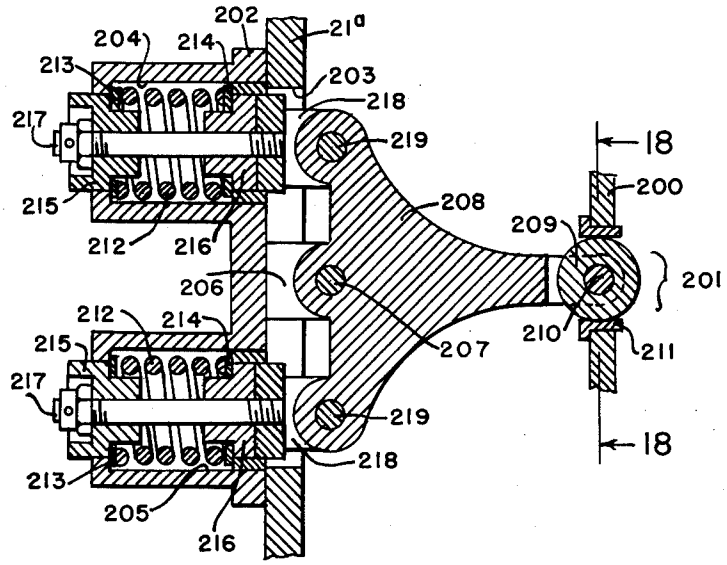



FIG. 18

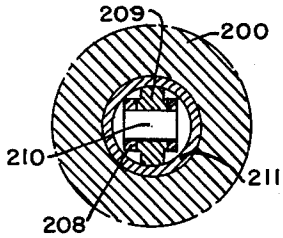
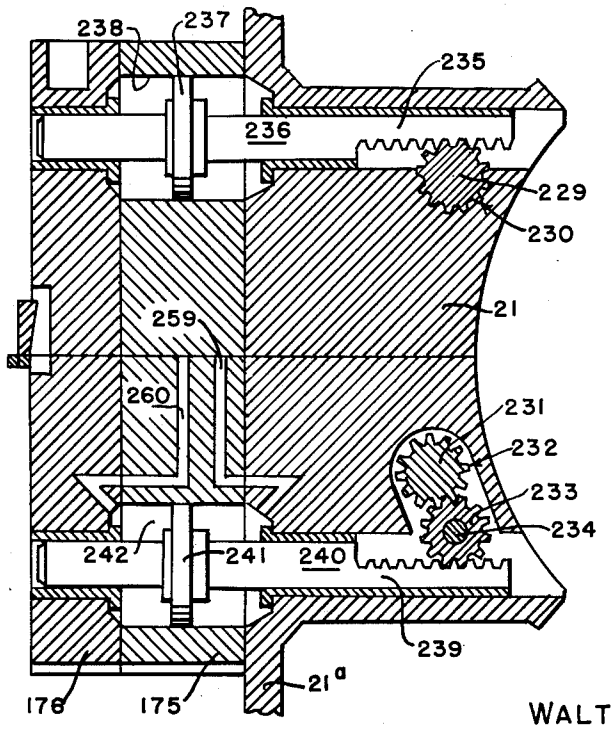



FIG. 19




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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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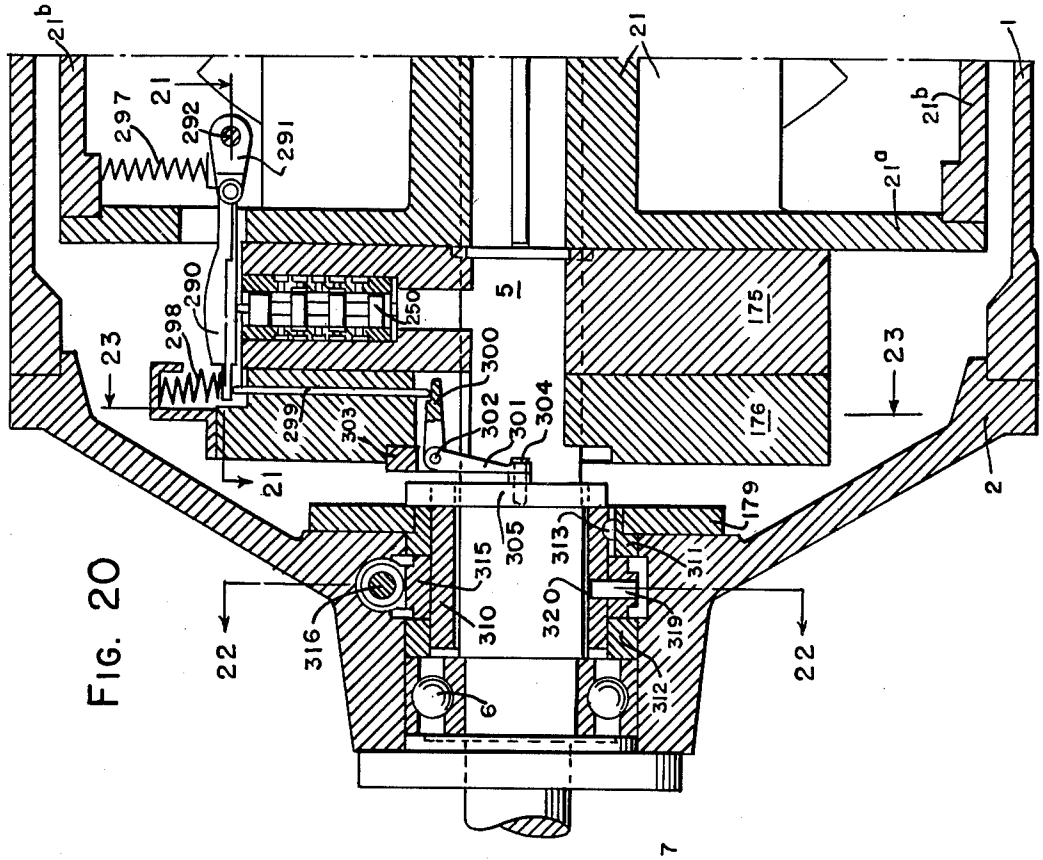



FIG. 20

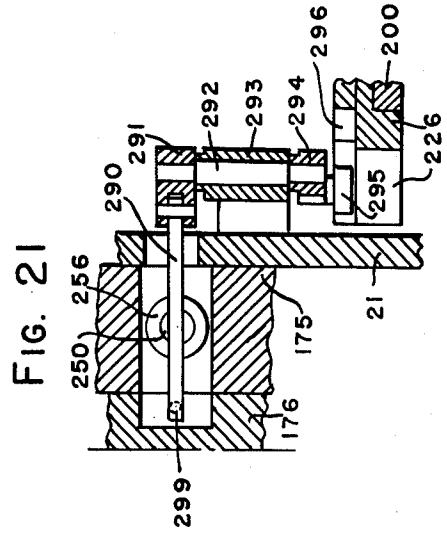



FIG. 21

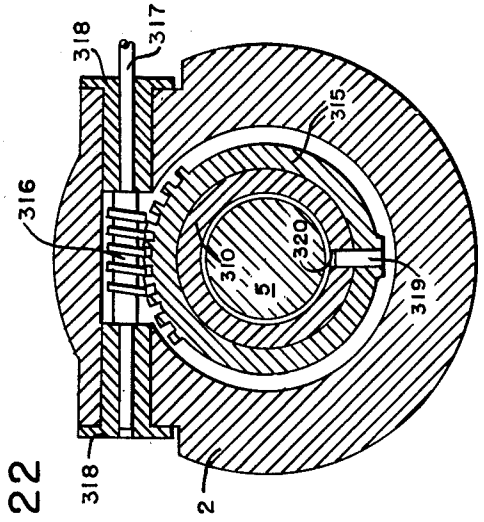



FIG. 22

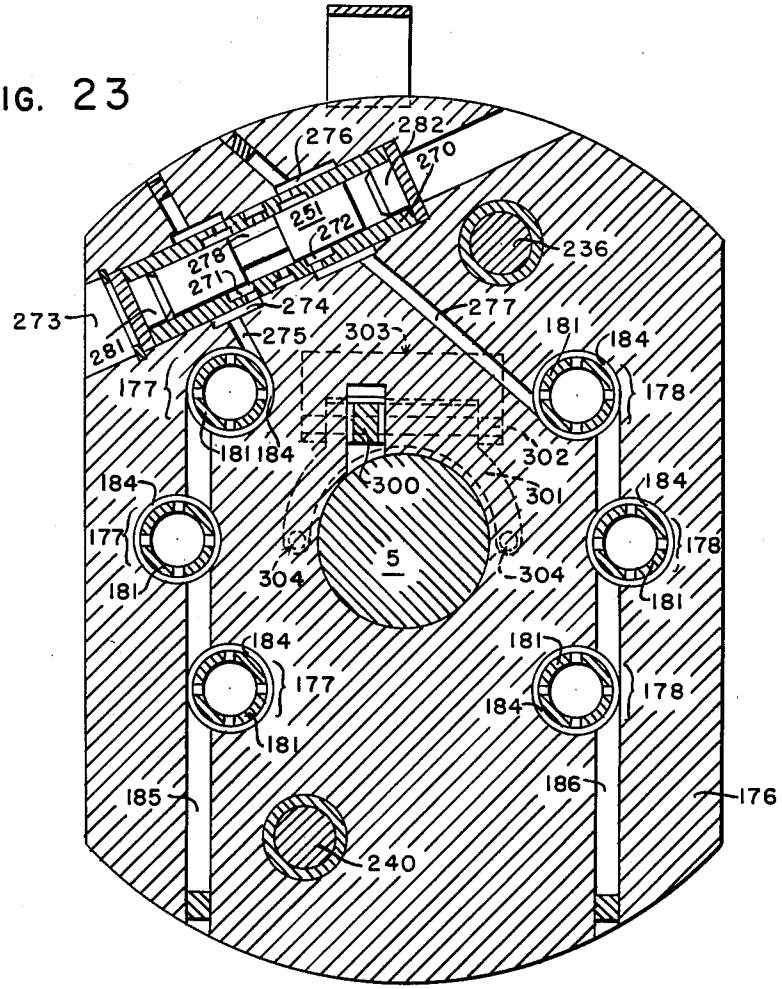
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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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FIG. 23




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AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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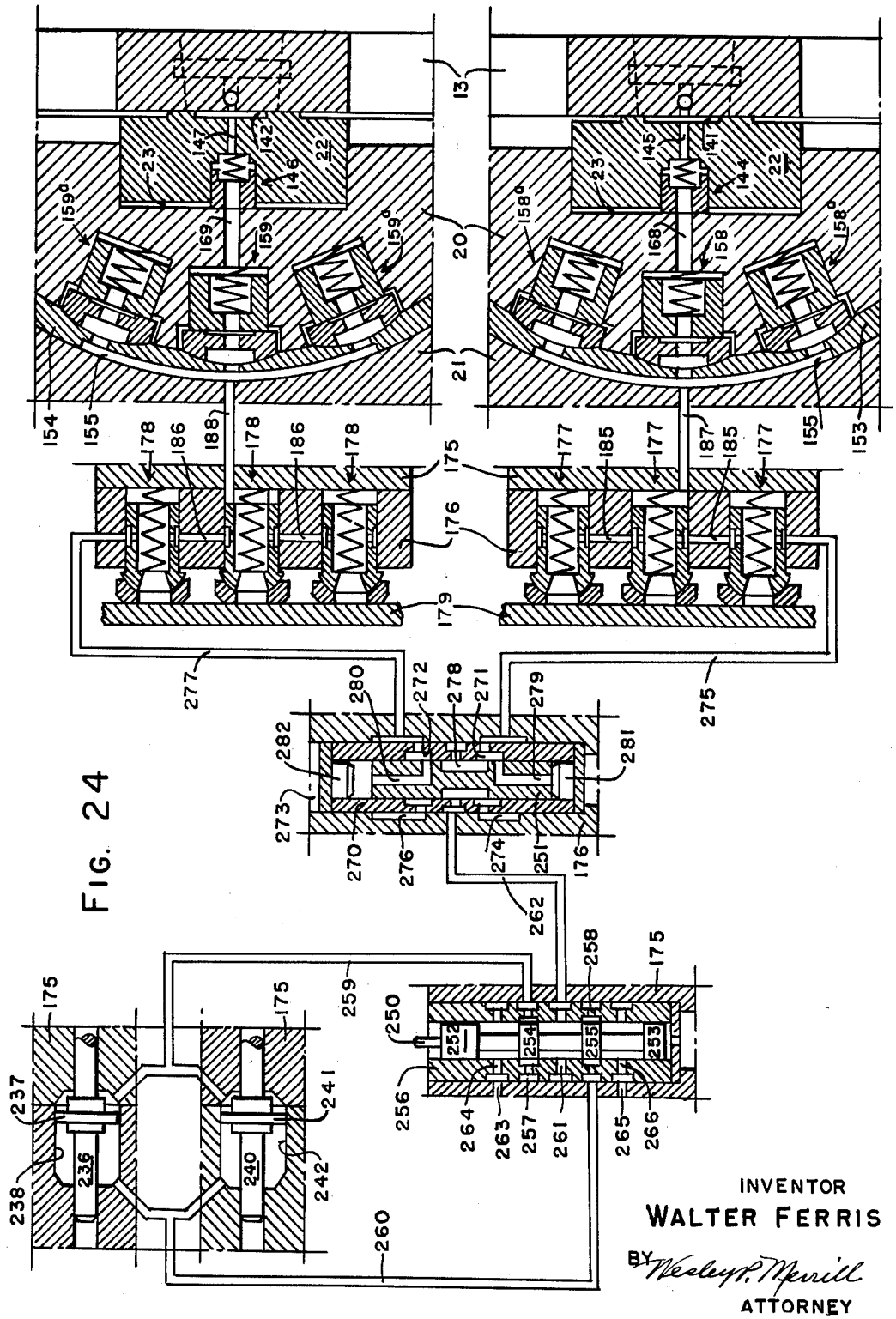


FIG. 24

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United States Patent Office 2,737,894 Patented Mar. 13, 1956



2,737,894

# AXIAL TYPE PUMP WITH STATIONARY CYLINDERS

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

Application August 15, 1952, Serial No. 304,477

16 Claims. (Cl. 103—5)

This invention relates to multiple piston axial type pumps for pumping liquid at high pressures, the liquid usually being employed to energize hydraulic motors. The pump includes a cylinder barrel or block in which the pistons and cylinders are arranged in one or more circular rows about a central axis and are usually parallel to each other and to the axis. In a pump embodying the invention, the cylinder block is non-rotatable, such as by being fixed to or forming part of the main frame, and the pistons are reciprocated by a driving plate or cam which is inclined to and fixed for rotation with a drive shaft the axis of which coincides with the axis of the cylinder block. However, certain features of the invention may also be embodied in conventional types of axial pumps in which the cylinder barrel or block is rotatable and the pistons are reciprocated by a driving plate or cam which is mounted in the casing and is inclined at an angle to the axis of the cylinder barrel.

The present invention has as an object to provide a pump capable of discharging a larger volume of liquid at high pressures than the pumps which were heretofore commercially available.

Another object is to provide a pump in which the flow of liquid to and from each cylinder is controlled by a separate valve, and the several valves are operated in timed sequence with the strokes of the corresponding pistons.

Another object is to provide a pump having each cylinder ported during the greater part of its stroke through a mechanically actuated valve of ample capacity to take the maximum flow, but ported during the end portions of each stroke only through auxiliary valves especially adapted to prevent shocks at the opening and closing of discharge port.

Another object is to provide a pump in which a separate valve controls each cylinder and each valve will not connect its cylinder to the discharge port until after the piston in its cylinder has created a pressure higher than the pressure in the discharge port.

Another object is to provide a machine of the above type with improved means for transmitting motion between the shaft and the pistons.

Other objects and advantages will appear from the description hereinafter given of a pump in which the invention is embodied.

The invention is exemplified by the pump shown in part schematically in the accompanying drawings in which the views are as follows:

Fig. 1 is in part an elevation of and in part a longitudinal vertical central section through a pump in which the invention is embodied, the plane of the view being indicated by the line **1—1** of Fig. 2.

Fig. 2 is a transverse vertical section taken on the line **2—2** of Fig. 1 but drawn to a larger scale.

Fig. 3 is a transverse vertical sectional view illustrating the trunnions for a counterweight and also for a wobble plate which effects reciprocation of the pumping pistons in response to rotation of a drive shaft, the view being taken on the line **3—3** of Fig. 1 but drawn to approximately the same scale as Fig. 2.



Fig. 4 is a sectional plan view taken through the pumping portion of the pump on the irregular line **4—4** of Fig. 2.

Fig. 5 is a sectional plan view taken through the other end portion of the pump on the line **5—5** of Fig. 3.

Fig. 6 is an end view of the pump with a cover plate removed and illustrates the mechanism for shifting the valves which control the main flow of liquid to and from the pump cylinders, the view being taken on the line **6—6** of Fig. 1 but drawn to approximately the same scale as Fig. 2.

Fig. 7 is a view showing two check valves through which liquid may flow to and from a cylinder when the valve which controls the main flow of liquid to and from that cylinder is closed, the view being taken in the same plane as Fig. 1 but drawn to a considerably larger scale.

Fig. 8 is a view illustrating how each piston is connected to the wobble plate which effects reciprocation of the pistons, the view being taken in the same plane as Fig. 1 but drawn to approximately the same scale as Fig. 7.

Fig. 9 is a diagram of the hydraulic circuit in the pumping portion of the pump, only four of the pistons and the valves associated therewith being shown.

Fig. 10 is a view of the front face of the wobble plate, the view being taken on the line **10—10** of Fig. 1 but drawn to a larger scale.

Fig. 11 is a rear face view of an element which engages the front face of the wobble plate and functions both as a hydraulic thrust bearing and as a valve, the view being taken on the line **11—11** of Fig. 1 but drawn to approximately the same scale as Fig. 10.

Fig. 12 is a section taken through a part of the thrust bearing shown in Fig. 11 and through a rocker which supports the thrust bearing and is tiltable to vary the displacement of the pump, the view being drawn to approximately the same scale as Fig. 11 and taken in the plane indicated by the line **12—12** of Fig. 5 and also indicated by the line **12—12** of Fig. 11.

Fig. 13 is a developed face view of a liner through which forces are transmitted between the arcuate face of the rocker and a driving head through which rotation is transmitted from the drive shaft to the rocker and the wobble plate, the view being indicated by the arcuate line **13—13** of Fig. 12.

Fig. 14 is a section taken on the line **14—14** of Fig. 13.

Fig. 15 is a transverse sectional view showing a part of the mechanism for tilting the rocker and for also tilting in the opposite direction a counterweight which is provided to neutralize the unbalanced centrifugal forces in the rocker and the wobble plate, the view being taken on the irregular line **15—15** of Fig. 1 but drawn to approximately the same scale as Figs. 2–6.

Fig. 16 is a longitudinal vertical sectional view showing the rocker and a part of the tilting mechanism, the plane of the view being indicated by the line **16—16** of Fig. 5 and by the line **16—16** of Fig. 15.

Fig. 17 is a section through a mechanism for applying spring force to the counterweight, the view being taken on the line **17—17** of Fig. 5.

Fig. 18 is a section taken on the line **18—18** of Fig. 17.

Fig. 19 is a section through the driving head and certain adjacent parts taken on the irregular line **19—19** of Fig. 15 and showing the hydraulic motors for tilting the rocker and the counterweight.

Fig. 20 is a longitudinal vertical section through the portion of the pump which is shown in elevation in Fig. 1, the view being taken on the irregular line **20—20** of Fig. 5 and showing a part of the mechanism for controlling the hydraulic motors shown in Fig. 19.

Fig. 21 is a fragmentary plan view taken on the irregular line 21—21 of Fig. 20.

Fig. 22 is a transverse section taken on the line 22—22 of Fig. 20.

Fig. 23 is a vertical transverse section taken on the line 23—23 of Fig. 20 but drawn to a larger scale.

Fig. 24 is a diagram of the hydraulic circuit in the driving portion of the pump.

Fig. 25 is a diagrammatic view of the piston recipocating mechanism.

The pump illustrated is so large and the scale of the drawings is necessarily so small that some clearances and the sizes of some parts had to be exaggerated and some features, such as sealing means and bearings for rotating parts, had to be omitted.

*General arrangement*

The pump has the greater part of its mechanism arranged within a casing 1 which has an end head 2 rigidly attached to and closing its front end and a cylinder block 3 closely fitted in and rigidly attached to its rear end portion. Casing 1 is adapted to be mounted upon a reservoir 4 which has not been shown in connection with casing 1 but has been shown schematically in Fig. 9.

A drive shaft 5 extends through casing 1 upon approximately the horizontal centerline thereof and is rotatably supported by a bearing 6 carried by end head 2, by a bearing 7 carried by cylinder block 3 at the front end thereof and by a bearing 8 carried by cylinder block 3 at the rear end thereof, bearings 7 and 8 being spaced apart by a spacer tube 9 arranged upon shaft 5.

Cylinder block 3 has a plurality of cylinders 10 formed therein in a circular row concentric with shaft 5. A piston 11 is fitted in each cylinder 10 and is connected by a connecting rod 12 to a non-rotating thrust member or wobble plate 13 which is rockably supported at its center upon a stationary hollow ball 14 the center of which is on the axis of shaft 5 and through which shaft 5 extends with sufficient clearance to prevent the shaft from contacting the ball. As shown, ball 14 is provided with an annular flange $14^a$ which is rigidly secured to the front end of cylinder block 3. Wobble plate 13 is provided with an annular split bearing $13^a$ which is closely fitted therein and has an internal spherical surface complementary to and closely fitted upon ball 14 to rock thereon. The means for lubricating ball 14 has not been shown as it forms no part of the present invention.

Rotation of wobble plate 13 is prevented by a universal joint the ring 15 of which has wobble plate 13 pivotally connected thereto at diametrically opposite points by two pins 16 as shown in Figs. 1 and 3. Ring 15 is pivoted at points spaced 90° from pins 16 upon two pins 17 (Figs. 3 and 5) arranged in the bifurcated ends of two arms 18 each of which is slidably supported in a bracket 19 carried by casing 1. The extended axes of pins 16 and 17 pass through the center of ball 14.

Wobble plate 13 is restrained from axial movement against the thrust of pistons 11 by a rocker 20 which is arranged within a driving head 21. As will presently be more fully explained, rocker 20 and driving head 21 are fixed for rotation with shaft 5 and are restrained from axial movement. The forces which prevent axial movement of wobble plate 13 are transmitted through a hold-up element 22, which has been shown as engaging the flat front face of wobble plate 13 and which is arranged in a recess 23 extending into rocker 20 from the flat rear face thereof, and through a plurality of piston shoes 24 each of which is associated with a connecting rod 12 and bears against the flat rear face of rocker 20 radially outward from element 22. The front face of rocker 20 and the rear face of driving head 21 are cylindrcal and are accurately machined to radii struck from the center of ball 14. Concavo-convex liners (not appearing in Fig. 1) are closely fitted between the cylindrical surfaces to transmit axial forces from one to the other and to permit relative radial movement therebetween.

The arrangement is such that rocker 20 may be swung about the center of ball 14 either upward or downward in respect to Fig. 1 to accurately adjusted positions at one side or the other of the neutral position shown in Fig. 1. Swinging rocker 20 away from its neutral position causes its rear face to be inclined to the axis of shaft 5 and to gyrate about the shaft axis as the shaft and rocker 20 rotate. Since shoes 24 bear against the rear face of rocker 20, gyration of that face causes wobble plate 13 to pivot upon pins 16, ring 15 to pivot upon pins 17 and wobble plate 13 to wobble upon ball 14, thereby effecting reciprocation of pistons 11.

*The pumping mechanism*

Cylinder block 3 is cylindrical and is closely fitted in a bore 25 formed in the rear end portion of casing 1. As shown in Figs. 1, 2 and 4, each of cylinders 10 has a piston valve 26 associated therewith and the several valves are arranged in a circular row concentric with the row of cylinders 10. Each valve 26 is preferably fitted in a ported sleeve which is arranged in a bore formed in cylinder block 3 but in order to simplify the drawings each valve 26 has been shown fitted for reciprocation in a bore 27 which is formed in cylinder block 3 and has three annular grooves or ports 28, 29 and 30 formed in its wall. Each port 28 communicates through a passage 31 (Fig. 2) with one of the cylinders 10. Each port 29 communicates through a passage 32 with an annular passage 33 which is formed in the wall of the bore 25 in casing 1 and communicates with a passage 34 (Fig. 4) by means of which the pump may be connected to one side of a hydraulic circuit. Each port 30 communicates through a passage 35 with an annular passage 36 which is formed in the wall of bore 25 and communicates with a passage 37 (Fig. 4) by means of which the pump may be connected to the other side of the hydraulic circuit.

Valves 26 may be made large enough to permit cylinders 10 to be filled with liquid from an adjacent reservoir in response to retraction of pistons 11 but the size of valves 26 and the forces required to reciprocate them may be considerably reduced if the pump is supercharged at a pressure, such as 35 p. s. i., which is relatively low but is high enough to obtain the necessary velocity of the liquid passing through the valves 26 on the intake side of the pump.

As shown schematically in Fig. 9, liquid for supercharging the pump may be supplied by an auxiliary pump 40 which draws liquid from reservoir 4 and discharges it through a channel 41, a selector valve 42 and either a channel 43 into passage 33 or through a channel 44 into passage 36. Since the pump may be employed in a differential hydraulic circuit, a low pressure relief valve 45 is connected to channel 41 and discharges into reservoir 4 so that whenever liquid is returned to the main pump in excess of the liquid required to fill cylinders 10, the excess liquid may be exhausted through relief valve 45.

Since the pressure required to supercharge the main pump is low, supercharge pump 40 may be of a constant displacement type and the liquid discharged by it in excess of the liquid required to fill cylinders 10 may be exhausted through relief valve 45. But preferably the supercharge pump is a "constant pressure" pump. That is, a pump which will discharge liquid at a predetermined maximum rate until it creates a predetermined pressure and then it will automatically reduce its displacement until it is delivering just enough liquid to maintain that pressure substantially constant, such as the supercharge pump shown in Patent No. 2,484,337.

Selector valve 42 includes a body 46 which is fastened to casing 1 and has an axial bore 47 and three annular grooves or ports 48, 49 and 50 formed in the wall of bore 47. Port 48 is connected by channel 41 to pump 40, port 49 is connected by channel 43 to passage 33 and port 50 is connected by channel 44 to passage 36. Communication between port 48 and ports 49 and 50 is controlled by

a valve plunger 51 which is fitted in bore 47 and has two ducts 52 and 53 extending into it from its opposite ends and then extending radially outward into communication with ports 49 and 50 respectively.

The arrangement is such that, when high pressure is created in passage 33, liquid will flow therefrom through channel 43, port 49 and duct 52 to one end of bore 47 and will shift plunger 51 into the position shown and plunger 51 will open port 50 to port 48 so that liquid can flow from pump 40 through channel 41, selector valve 42 and channel 44 into passage 36 and, when high pressure is created in passage 36, liquid will flow therefrom through channel 44, port 50 and duct 53 to the other end of bore 47 and will shift plunger 51 into its other position and plunger 51 will open port 49 to port 48 so that liquid can flow from pump 40 through channel 41, selector valve 42 and channel 43 into passage 33.

Port 48 in valve 42 is also connected by a passage 54 to an annular passage 55 which extends around cylinder block 3 and has been shown as being formed in part in casing 1 and in part in cylinder block 3. Passage 55 is thus continuously supplied with supercharging liquid.

The mechanism for shifting valves 26 has been shown in Figs. 1, 4 and 6 as being arranged within a cylindrical housing 58 which is attached to the rear end of cylinder block 3 and is closed at its rear end by a cover plate 59. Each of valves 26 has a universal joint 60 fixed to its rear end and connected by linkage 61 to one of the several arms 62 of a valve actuator 63 which is journaled as by means of bearings 64 upon a tubular cam 65 which is fixed upon the rear end portion of shaft 5. The axis of the outer periphery of cam 65 is inclined to the axis of the inner periphery thereof so that actuator 63 is inclined to the axis of shaft 5.

Actuator 63 is pivoted at diametrically opposed points on its horizontal center line to a ring 66 by two pins 67. Ring 66 is pivoted at diametrically opposite points on its vertical center line upon two pins 68 carried by two arms 69 which are supported in two brackets 70 carried by housing 58. The arrangement is such that, when shaft 5 is rotated, cam 65 will cause actuator 63 to pivot upon pins 67, ring 66 to pivot upon pins 68 and actuator 63 to wobble about the intersection of the axes of shaft 5 and pins 67.

Cam 65 is fixed upon shaft 5 in such a position that, when rocker 20 is adjusted to cause wobble plate 13 to be inclined to the axis of shaft 5 as previously explained, the plane of valve actuator 63 will be spaced 90° from the plane of wobble plate 13. The arrangement is such that, when the pump is pumping liquid and any piston 11 is at either end of its stroke, the valve 26 associated with the cylinder containing that piston will be in its closed position and will be blocking the port 28 leading to that cylinder as shown in Fig. 1. Instantly thereafter, both the piston and the valve start to move but the piston will be moving at its slowest speed while the valve will be moving at its highest speed so that the valve will quickly open port 28. The piston will accelerate and the valve will decelerate until the piston is at half stroke at which time the valve will be fully open as shown in Fig. 4. Then the piston will decelerate and the valve will accelerate until the piston reaches the other end of its stroke at which time the valve will have closed port 28 as shown in Fig. 1.

In Fig. 25 driving head 21 has been shown in the same position as in Fig. 1 but rocker 20 has been shown as having been swung downward in respect to Fig. 1 so that its rear face is inclined to the axis of shaft 5 and will gyrate about the shaft axis when shaft 5 and rocker 20 are rotated. The thrust of pistons 11 holds piston shoes 24 against the rear face of rocker 20 and thereby maintains wobble plate 13 parallel to the rear face of rocker 20. Two diametrically opposite points at which piston shoes 24 contact the rear face of rocker 20 have been indicated at A and B, point A being the contact point farthest from cylinder block 3 and point B being the contact point nearest to cylinder block 3.

With rocker 20 in the position shown in Fig. 25, the upper piston designated $11^x$ is at the end of its outstroke and its shoe 24 is in contact with the rear face of rocker 20 at point A. Cylinder block 3 contains an odd number of cylinders so that no two pistons are diametrically opposite each other but, for the purpose of this explanation, a piston $11^y$ has been shown diametrically opposite piston $11^x$ in Fig. 25 with the shoe 24 of the lower piston $11^y$ in contact with the rear face of rocker 20 at point B, in which position piston $11^y$ is at the end of its in-stroke.

When shaft 5 is rotated in the direction indicated by the arrow on Fig. 25, driving head 21 and rocker 20 will rotate with it and the rear face of rocker 20 will slide across the faces of the several piston shoes 24. During the first half-revolution of rocker 20 from the position shown in Fig. 25, its rear face will move the shoe 24 of upper piston $11^x$ rearward or inward harmonically until point B comes into alinement with that shoe at which time piston $11^x$ will have been moved to the end of its in-stroke or into a position corresponding to the position of piston $11^y$ shown in Fig. 25.

During the next half-revolution of rocker 20, its rear face will permit the shoe 24 of piston $11^x$ to be moved forward harmonically. If the pump is supercharged as shown, piston $11^x$ will be moved forward or outward by the supercharge pressure. If the pump is not supercharged, piston $11^x$ will be drawn forward or outward by wobble plate 13. In either case, piston $11^x$ will be moved forward or outward harmonically until point A comes into alinement with the shoe 24 of that piston at which time piston $11^x$ will have made a complete reciprocation and will be in the position shown in Fig. 25. Continuous rotation of rocker 20 will cause continuous reciprocation of the piston.

All of the pistons 11 are reciprocated in the same manner, the pistons whose shoes 24 are in contact with that half of rocker 20 which is the far half in respect to Fig. 25 being forced progressively rearward or inward and the pistons whose shoes 24 are in contact with that half of rocker 20 which is the near half in respect to Fig. 25 being moved progressively forward or outward.

As each piston 11 starts to move inward or rearward in its cylinder, the valve 26 associated with that cylinder will move in a direction to connect its port 28 to its port 29 and, as each piston 11 starts to move outward or forward in its cylinder, the valve 26 associated with that cylinder will move in a direction to connect its port 28 to its port 30. The inward moving pistons will discharge liquid from their cylinders through passages 31, ports 28, valve bores 27, ports 29 and passages 32 into annular passage 33 and thence through passage 34 to one side of an external circuit. The cylinders containing outward moving pistons will be supplied with liquid through passages 31, ports 28, valve bores 27, ports 30 and passages 35 from annular passage 36. Part or all of the liquid required to fill the cylinders may be supplied to passage 36 through passage 37 from the external circuit or a part or all of the liquid required to fill the cylinders may be supplied to passage 36 through passage 44, selector valve 42 and passage 41 from supercharge pump 40.

If rocker 20 is swung upward from its neutral position, the pump will function in the above described manner except that the movement of the pistons will be reversed, the pistons will discharge liquid into annular passage 36 and the cylinders will be supplied with liquid from annular passage 33.

When the pump is creating a high pressure and a piston starts to move inward, the liquid in the cylinder containing that piston is initially under a low pressure if the pump is supercharged, or it is under a negative pressure

and the cylinder may not be completely filled with liquid if the piston has to draw liquid into its cylinder from a reservoir, but the discharge passage 33 or 36 contains liquid at the high pressure. Therefore, if each valve 26 opened the associated cylinder to the discharge passage at the instant that the piston in that cylinder started to move inward, the high pressure in the discharge passage would cause liquid to flow therefrom into the cylinder and cause a shock with resultant noise and energy loss. These shocks in pumps now in use often disintegrate the metal in the port walls.

In order to eliminate such shocks and noise, each valve 26 is so proportioned that it does not open the associated cylinder to the discharge passage until after the piston in that cylinder has moved inward far enough to create in its cylinder a pressure approximately as high as the pressure in the discharge passage and each cylinder is provided with an outlet check valve 71 through which the piston may discharge liquid before the valve 26 opens.

If the pump is reversible as shown, each valve 26 must be so proportioned that it will not open its port 28 to either its port 29 or its port 30 until after it has moved a predetermined distance in one direction or the other from its neutral position. In that case, it is preferred to provide each cylinder 10 with an inlet check valve 72 through which, as the piston in that cylinder moves outward during the first part of intake stroke, liquid may flow to the cylinder until the valve 26 associated with that cylinder has moved far enough to connect that cylinder to the passage 33 or 36 which at that time is the inlet passage. If such a check valve be not provided, the cylinder is temporarily starved at the beginning of the instroke, and gas may be formed in the liquid in the cylinder.

While any suitable type of check valve will suffice, check valves 71 and 72 preferably are so constructed that each may be readily inserted into and removed from cylinder block 3. As shown in Fig. 7, the check valves 71 and 72 for each cylinder 10 are arranged, respectively, in two bores 73 and 74 formed in cylinder block 3 at the rear of that cylinder. Check valve 71 includes a body 75, which is threaded into bore 73 and has an axial bore 76 formed therein, and an annular valve seat 77 the opening through which is concentric with bore 76 and communicates with cylinder 10. Bore 76 has a valve plunger 78 fitted therein and urged against valve seat 77 by a spring 79. Body 75 also has formed in its outer periphery intermediate its ends a cannelure 80 through which liquid may flow to check valve 72 as will presently be explained. The inner part of bore 73 between body 75 and valve seat 77 communicates through a passage 81 with an annular passage 82 which is formed in casing 1 and extends around cylinder block 3. Suitable means are provided for subjecting the spring end of plunger 78 to the pressure prevailing in passage 82, such as a groove 83 formed in the periphery of plunger 78.

As shown in Figs. 1 and 9, annular passage 82 is adapted to be connected to either passage 33 or passage 36 under the control of an automatic selector valve 84 which is fitted in a bore 85 formed in a valve body 86 attached to casing 1. Bore 85 has three annular grooves or ports 87, 88 and 89 formed in the wall thereof. Port 87 is connected to passage 82 by a passage 90, port 88 is connected to passage 33 by a passage 91 and port 89 is connected to passage 36 by a passage 92. Valve 84 has two ducts 93 and 94 extending into it from its opposite ends and then extending radially outward into communication with ports 88 and 89 respectively.

The arrangement is such that, when high pressure is created in passage 33, liquid will flow therefrom through passage 91, port 88 and duct 93 into the left end of bore 85 and will move valve 84 against the right end of bore 85 in which position valve 84 will connect passage 82 to passage 33 through passage 90, valve body 86 and passage 91 and, when high pressure is created in passage 36, liquid will flow therefrom through passage 92, port 89 and duct 94 into the right end of bore 85 and will move valve 84 against the left end of bore 85 in which position valve 84 will connect passage 82 to passage 36 through passage 90, valve body 86 and passage 92.

Referring again to Fig. 7, check valve 72 includes a body 95 which is threaded into bore 74 and has a bore 96 extending into it from its inner end and a smaller bore 97 extending farther into it from the end of bore 96. A valve plunger 98 is fitted in bore 96 and is urged by a spring 99 against the shoulder formed at the junction of bores 96 and 97, thereby normally preventing flow of liquid from one bore to the other.

Valve body 95 also has two cannelures 100 and 101 formed in its peripheral surface and spaced from each other. Cannelure 100 communicates with cylinder 10 through a passage 102 and it communicates with the opposite ends of bore 96 through two sets of holes 103 and 104 respectively. Cannelure 101 communicates with bore 97 through a plurality of holes 105 and it is connected to supercharge passage 55 by a passage 106 which is intersected by bore 73 in the plane of cannelure 80.

The arrangement is such that the supercharge pressure, which is constantly maintained in passage 55, extends through passage 106, cannelure 101 and holes 105 into bore 97 and tends to move plunger 98 to open position but any pressure in cylinder 10 extends therefrom through passage 102, cannelure 100 and holes 103 into the spring end of bore 96 and assists spring 99 in holding plunger 98 in its closed position. When piston 11 is retracted, the pressure in cylinder 10 will drop until the force exerted upon plunger 98 by spring 99 and by any pressure in cylinder 10 is less than the force exerted upon plunger 98 by the supercharge pressure. Then the preponderance of force exerted upon plunger 98 by the supercharge pressure will move plunger 98 to its open position and liquid will flow from supercharge passage 55 through passage 106, cannelure 101, holes 105, bore 97, holes 104, cannelure 100 and passage 102 into cylinder 10 and will fill cylinder 10 with liquid as fast as piston 11 is retracted.

Referring now to Fig. 9 and assuming that the pump is adjusted to cause the pistons 11 to discharge into passage 33 as previously explained, the pistons 11 which are moving inward but are not near either the inner or the outer ends of their strokes are represented by the piston $11^a$ and the cylinder containing that piston and the valves associated therewith are indicated by their reference numerals with the exponent "*a*" added thereto. The pistons which are near the inner ends of their strokes are represented by the piston $11^b$ and the cylinder containing that piston and the valves associated therewith are indicated by their reference numerals with the exponent "*b*" added thereto. The pistons 11 which are moving outward but are not near either the inner or the outer ends of their strokes are represented by the piston $11^c$ and the cylinder containing that piston and the valves associated therewith are indicated by their reference numerals with the exponent "*c*" added thereto. The pistons 11 which are near the outer ends of their strokes are represented by the piston $11^d$ and the cylinder containing that piston and the valves associated therewith are indicated by their reference numerals with the exponent "*d*" added thereto.

During the in-stroke of a piston $11^a$ as indicated by the large arrow thereon, it will discharge liquid from its cylinder $10^a$ through passage $31^a$, valve bore $27^a$, passage $32^a$ and discharge passage 33 to the external circuit as indicated by the small arrows on those passages. At the same time, each piston $11^c$ is being retracted, as indicated by the large arrow thereon, and liquid is being returned from the external circuit into passage 36. Since pump 40 is maintaining pressure in passage 36 as indicated in Fig. 9 and as previously explained,

the pressure in passage 36 will cause each cylinder $10^c$ to be supplied with liquid through passage $31^c$, valve bore $27^c$ and passage $35^c$ from passage 36 as indicated by the small arrows on those passages, valves $26^a$ and $26^c$ being at this time open wide enough to permit liquid to flow freely from cylinder $10^a$ to passage 33 and into cylinder $10^c$ from passage 36.

Just before each piston 11 reaches the end of its in-stroke, the valve 26 associated with that piston closes, as indicated by the position of valve $26^b$, and the piston continues to move inward as indicated by the full arrow on piston $11^b$. After valve $26^b$ closes, piston $11^b$ will discharge liquid from its cylinder $10^b$ through check valve $71^b$, passages $81^b$, 82 and 90, valve body 86 and passages 91 and 33 to the external circuit, as indicated by the full arrows on those passages, until the contact point B (Fig. 25) on the rear face of rocker 20 comes into alinement with the shoe 24 on that piston at which time the piston is at the end of its in-stroke as previously explained.

Each piston 11 starts to retract, as indicated by the dotted arrow on piston $11^b$, the instant that contact point B moves out of alinement with the shoe 24 of that piston. At the end of the in-stroke, some liquid at pump pressure remains in the cylinder and, if the cylinder were opened to the intake the instant that the piston started to retract as is the case in conventional pumps, the energy required to compress that liquid to pump pressure would be wasted. In the present case, the valve 26 associated with that cylinder remains closed until shaft 5 has rotated through a predetermined angular distance. During that time, the pressure in the cylinder reacts against the inclined rear face of rocker 20 and, the instant that contact point B on the rear face of rocker 20 moves beyond the axis of the shoe 24 of the piston in that cylinder, the liquid in the cylinder expands and assists in rotating shaft 5, thereby regenerating a large part of the energy required to compress to pump pressure the liquid remaining in each cylinder at the end of the instroke of the piston in that cylinder.

As soon as the liquid remaining in cylinder $11^b$ has expanded to such an extent that the pressure in cylinder $11^b$ is enough less than the supercharge pressure to permit check valve $72^b$ to open, liquid will flow from supercharge passage 55 through passage $106^b$, check valve $72^b$ and passage $102^b$ to cylinder $11^b$ and keep it filled with liquid until shaft 5 has rotated through an angular distance great enough to cause valve actuator 63 to open valve $26^b$ and thereby permit the cylinder to be filled with liquid from passage 36 as explained above and as shown in Fig. 9 by the arrows which indicate the flow of liquid into cylinder $10^c$.

Just before each piston 11 reaches the end of its out-stroke, the valve 26 associated with that piston closes, as indicated by the position of the valve $26^d$, and the piston continues to move outward as indicated by the dotted arrow on piston $11^d$. After valve $26^d$ closes, liquid is supplied to cylinder $10^d$ from supercharge passage 55 through passage $102^d$, check valve $72^d$ and passage $106^d$, as indicated by the dotted arrows on those passages.

Each piston 11 starts to advance, as indicated by the full arrow on piston $11^d$, instantly after it reaches the end of its out-stroke but valve $26^d$ is closed at that instant so that piston $11^d$ cannot discharge liquid from cylinder $10^d$ until after it has created therein a pressure somewhat higher than the pressure in passages 33 and 82. Then check valve $71^d$ will open and piston $11^d$ will discharge liquid from its cylinder $10^d$ through check valve $71^d$, passages $81^d$, 82 and 90, valve body 86 and passages 91 and 33 to the external circuit, as indicated by the small full arrows on those passages, until piston $11^d$ has advanced a short distance and then valve $26^d$ will open and permit the piston to discharge liquid into passage 33 as explained above and as shown by the discharge of liquid from cylinder $10^a$.



*The piston and wobble plate assembly*

Pistons 11 may be retracted either by supplying liquid to cylinders 10 at a sufficiently high pressure or by connecting pistons 11 to wobble plate 13 by suitable linkages such as the connecting rods 12. As shown in Fig. 8, each piston 11 has a spherical head 109 fixed to its outer end and fitted into a socket 110 formed upon one end of a short push rod 111 having a spherical head 112 formed upon its other end. Head 112 is fitted in a spherical socket 113 which has a shank 114 formed integral therewith and rigidly secured in wobble plate 13. An annular socket 115 is fitted upon the outer spherical surface of socket 113 and is connected to a sleeve 116 which encloses head 109 and socket 110 and has an annular inward flange 117 on its rear end. Flange 117 is engaged by a spring 118 which urges an annular spherical socket 119 against the rear face of head 109 and thereby prevents separation of ball and socket joint 109—110 and separation of ball and socket joint 112—113.

The arrangement is such that piston 11 may be drawn outward or forward by a retraction force transmitted thereto through its head 109, socket 119, spring 118, flange 117, sleeve 116 and sockets 115 and 113 from wobble plate 13, and piston 11 may be forced inward or rearward by a pumping force transmitted thereto through its head 109, rod 111, head 112 and socket 113. The pumping force is transmitted from rocker 20 to socket 113 partly through wobble plate 13 and partly through a shoe to be presently described.

In order to provide hydraulic thrust bearings in the ball and socket joints and to provide liquid for lubrication and other purposes, a recess 120 is provided between head 109 and socket 110, such as by flattening the end of head 109, and piston 11 is provided with an axial duct 121 which extends from recess 120 through piston 11 into communication with cylinder 10 (see Fig. 7) so that liquid can flow from cylinder 10 into recess 120. A recess 122 is similarly provided between head 112 and socket 113 and is supplied with liquid through a duct 123 which extends through ball 112 and rod 111 into communication with recess 120.

When pressure prevails in cylinder 10, liquid spreads over the spherical mating surfaces of the heads and the sockets and forms lubricating films therebetween. The area of each film into which pressure can extend should be limited and this may be accomplished by making socket 110 relatively short and by providing a suitably drained limit groove 124 in head 112. Any pressure in cylinder 10 will extend through duct 121 into recess 120 and through duct 123 into recess 122 so that the pressure in recesses 120 and 122 is the same as in cylinder 10. The pressure in the recesses will extend therefrom into the films of liquid between the mating surfaces of the balls and sockets. The film pressure at the edge of each recess will be the same as the pressure in the recess and will be substantially zero at edge of socket 110 and at the edge of groove 124. The liquid in each of recesses 120 and 121 acts as a liquid bearing between the ball and its socket and the area of each recess and the area of the film of liquid are such that the greater part of the pumping force is transmitted through the liquid in the recesses and the films containing pressure and only a small part of the pumping forces is transmitted through the films which have little or no pressure therein.

The pressure in the recess and in the film of liquid between each head and its socket tends to move the head away from its socket but the area of each recess and the area of the film containing pressure are so proportioned that the force exerted by the liquid upon each head is slightly less than the force exerted upon the inner end of the piston by the liquid in the cylinder.

A part of the pumping force required to advance piston 11 on a working stroke is transmitted from rocker 20 to socket 113 through the shoe 24 of that piston. Shoe

24 is arranged between the annular flat rear face of rocker 20 and the spherical head of a hold-up piston 126 which is fitted in an axial bore 127 formed in the shank 114 of socket 113. Piston 126 is hollow and has a spring 128 arranged therein to urge piston 126 against shoe 24 and shoe 24 against rocker 20. The contacting surfaces of rocker 20 and shoe 24 are made flat and smooth and the contacting surfaces of shoe 24 and piston 126 are made spherical and smooth to provide substantially liquid tight joints therebetween.

Shoe 24 is made annular to provide therein a pressure chamber 129, the interior of piston 126 is connected to chamber 129 through a passage 130 formed in the head end of piston 126 and bore 127 communicates through a passage 131 with recess 122 so that chamber 129 is continuously supplied with liquid at the pressure prevailing in cylinder 10.

When drive shaft 5 and rocker 20 are rotated, the rear face of rocker 20 will slide across the front faces of the several non-revolving shoes 24 and the liquid in the chambers 129 will provide liquid bearings between the shoes and the rocker. Also, liquid will seep from chambers 129 and provide a lubricating film between rocker 20 and the shoes. When rocker 20 is inclined to the axis of drive shaft 5 and is rotated, each piston will be progressively advanced during one-half of each revolution and will be progressively retracted during the other half of each revolution as previously explained. Each piston as it advances will create pressure in its cylinder and, since the same pressure prevails in chamber 129, that part of the pumping force which is transmitted from rocker 20 through shoe 24 is nearly all transmitted through the liquid in chamber 129 and only a small part thereof is transmitted through the film of liquid between the face of the shoe and the rear face of rocker 20.

Preferably, the area of each hold-up piston 126 is only about one-half the area of a pumping piston 11 so that only about one-half of the total pumping force is transmitted through the shoes 24. The other part of the total pumping force is transmitted from rocker 20 through element 22 and wobble plate 13 to the shanks 114 of sockets 113. Element 22 functions both as a hydraulic thrust bearing and as a valve, as will presently be explained, and it is supplied with liquid from cylinders 10.

It has previously been explained that the interior of each hold-up piston 126 is supplied with liquid at the pressure prevailing in the associated cylinder. As shown in Fig. 8, the interior of the piston 126 in each shank 114 communicates with a passage 133 which extends through the wall of shank 114 and communicates with one end of a passage 134 which extends approximately radially inward therefrom and then extends axially through the front face of wobble plate 13 into communication with element 22.

*The driving and hold-up mechanisms*

The outer ends of the several passages 134 are arranged in a circular row concentric with the axis of wobble plate 13 as shown in Fig. 10. Element 22 is fixed for rotation with rocker 20 and is provided with two arcuate grooves or ports 141 and 142 in axial alinement with the front ends of passages 134. Since wobble plate 13 is non-rotatable, rotation of element 22 with rocker 20 will cause the several passages 134 to register successively first with one and then with the other of ports 141 and 142.

Preferably, grooves 141 and 142 are formed in the rear face of element 22, a narrow annular wear plate is attached to element 22 and provided with two arcuate ports in registry with ports 141 and 142, and a narrow annular wear plate is attached to the rear face of wobble plate 13 and has a hole extending therethrough from the end of each passage 134. But in order to simplify the drawings, the wear plates have been omitted and element 22 has been shown in Fig. 11 as having a narrow annular boss 143 formed upon its rear face and ports 141 and 142 formed in boss 143.

While element 22 is fixed for rotation with rocker 20, it is free to move axially within recess 23 and it is urged against wobble plate 13 by a hold-up motor 144 and a plurality of hold-up motors $144^a$, each of which communicates with port 141 through a hole 145, and by a hold-up motor 146 and a plurality of hold-up motors $146^a$ each of which communicates with port 142 through a hole 147 so that motors 144 and $144^a$ are energized by liquid at the pressure prevailing in port 141 and motors 146 and $146^a$ are energized with liquid at the pressure prevailing in port 142. Hold-up motor 144 is arranged in element 22 at the center of port 141 and motors $144^a$ are arranged between motor 144 and the ends of port 141. Likewise, hold-up motor 146 is arranged in element 22 in the center of port 142 and motors $146^a$ are arranged between motor 146 and the ends of port 142.

As shown in Fig. 12, hold-up motor 144 includes a cylinder 148 which is formed in element 22, a piston 149 which is fitted in cylinder 148 and a spring 150 which urges piston 149 against the bottom of recess 23. Piston 149 has formed in its head end a hole 151 through which liquid may flow to other holdup motors as will presently be explained. Since motor 146 is identical to motor 144 and motors $144^a$ and $146^a$ are exactly like motor 144 except that hole 151 is omitted from the pistons thereof, they have not been shown in detail.

Before explaining more fully how pressures are maintained in ports 141 and 142, it should be explained that driving head 21 has its body portion fixed for rotation with drive shaft 5, as by being keyed or splined thereto, that it has a circular front flange $21^a$ formed integral with the body portion, and that it includes an annular shell $21^b$ which is fixed to flange $21^a$ concentric with shaft 5 and extends around rocker 20 and ring 15 as shown in Fig. 3.

The rear end portion of shell $21^b$ has two pins 152 arranged therein at diametrically opposite points and the inner ends of pins 152 are supported in two diametrically opposed webs $21^c$ shown as being formed integral with shell $21^b$. Pins 152 are arranged upon a common axis which extends through the center of ball 14.

Rocker 20 has two arms $20^a$ fixed thereto at opposite sides thereof and journaled, respectively, upon the two pins 152. When driving head 21 is rotated in response to shaft 5 being driven, rocker 20 will be rotated in synchronism with head 21 through pins 152 and arms $20^a$. Rocker 20 is adapted to pivot upon pins 152 to change pump displacement as will presently be explained.

As shown in Fig. 11, the adjacent ends of ports 141 and 142 are spaced from each other and the unbroken surfaces of the spaces between the adjacent ends of the two ports cooperate with the front face of wobble plate 13 to form seals between the two ports. Element 22 is fixed for rotation with rocker 20 in such a position that a line passing through the axis of shaft 5 and through the centers of the spaces between the adjacent ends of ports 141 and 142 is at right angles to the common axis of pins 152. With element 22 in that position, one of the ports 141 and 142 always registers with the passages 134 which communicate with the cylinders 10 containing inward moving pistons 11 and the other one of the ports 141 and 142 always registers with the passages 134 which communicate with the cylinders 10 containing outward moving pistons 11. Consequently, one of the ports 141 and 142 is continuously supplied with liquid at pump pressure and the other one of the ports 141 and 142 is continuously supplied with liquid at supercharge pressure.

The arrangement is such that a force proportional to pump pressure is transmitted from rocker 20 to wobble plate 13 through one-half of element 22 and a force proportional to the supercharge pressure is transmitted from rocker 20 to wobble plate 13 through the other half of element 22. The greater part of those forces are transmitted to wobble plate 13 through the liquid in

ports 141 and 142. Element 22 thus functions as a hydraulic thrust bearing through which forces are transmitted from rotatable rocker 20 to non-rotatable wobble plate 13 and it also functions as a valve for connecting one set of hydraulic motors 144 or 146 to the cylinders 10 containing inward moving pistons and for connecting the other set of hold-up motors 144 or 146 to the cylinders 10 containing outward moving pistons.

The front face of rocker 20 and the rear face of the body portion of driving head 21 are arcuate and have the radii thereof struck from the axis of pins 152. Rocker 20 has two curved liners 153 and 154 (Figs. 5, 12 and 13) arranged upon its arcuate front face at opposite sides of shaft 5. Preferably, each of the two liners engages a liner arranged upon the arcuate rear face of head 21 but in order to simplify the drawings the liners on head 21 have been omitted and liners 153 and 154 have been shown as engaging the arcuate rear face of head 21.

As shsown in Figs. 12 and 13, liner 153 has an elongated pressure chamber 155 formed in its front face and a drainage groove 156 extending around chamber 155 and spaced outward a short distance therefrom. A hole 157 extends through liner 153 at the center of chamber 155 and a hole 157a extends through liner 153 at each end of chamber 155. Since liner 154 is identical to liner 153, it has not been shown in detail and a description thereof is deemed unnecessary.

Liner 153 is urged against the arcuate rear face of driving head 21 by a hold-up motor 158 and two hold-up motors 158a which are arranged in rocker 20 at one side of shaft 5 with motor 158 concentric with the hole 157 in liner 153 and each of the motors 158a concentric with one of the holes 157a in liner 153. Likewise, liner 154 is urged against the arcuate rear face of driving head 21 by a hold-up motor 159 and two hold-up motors 159a which are arranged in rocker 20 at the other side of shaft 5 with motor 159 concentric with the hole 157 in liner 154 and each of the motors 159a concentric with one of the holes 157a in liner 154.

Hold-up motors 158, 158a, 159 and 159a are identical and, as shown in Fig. 12, each includes a cylinder 160 which is formed in rocker 20, a hollow piston 161 which is fitted in cylinder 160 and has a hole 162 extending through its head end, a sealing member 163 which is arranged between piston 161 and liner 153 or 154, and a spring 164 for urging piston 161 against sealing member 163 and member 163 against liner 153 or 154. The mating surfaces of piston 161 and member 163 are made flat and smooth and the mating surfaces of member 163 and liner 153 or 154 are made spherical and smooth to provide substantially liquid tight joints therebetween.

Sealing member 163 has two recesses 165 and 166 formed in its opposite faces concentric with hole 162 and a hole 157 or 157a and connected to each other by a hole 167 so that cylinder 160 and recesses 155, 165 and 166 are interconnected and any pressure therein will cause liquid to seep from chambers 155 and recesses 165 and 166 and form lubricating films between the mating surfaces of the piston, the sealing member, the liner and the driving head. The arrangement is such that the greater part of a force transmitted from driving head 21 to rocker 20 is transmitted through the liquid in chamber 155, the liquid in recesses 165 and 166 and the liquid in cylinder 160 to rocker 20 and only a small part of the force transmitted through the films of liquid between the metal parts.

Hold-up motor 158 communicates through a passage 168 with the hole 151 in the piston 149 of hold-up motor 144, as shown in Figs. 5 and 12, so that the pressure prevailing in port 141 will extend therefrom through hole 145, motor 144, hole 151, passage 168, motor 158 and hole 157 into the pressure chamber 155 in liner 153 and from chamber 155 through holes 157a into motors 158a so that the force transmitted from driving head 21 to rocker 20 through the liquid in pressure chamber 155 and through motors 158 and 158a is proportional to the pressure in port 141.

Likewise, hold-up motor 159 communicates through a passage 169 with the hole 151 in the piston of hold-up motor 146, as shown in Fig. 5, so that the pressure prevailing in port 142 will extend therefrom through hole 147, motor 146, hole 151, passage 169, motor 159 and hole 157 into the pressure chamber 155 in liner 154 and from chamber 155 through holes 157a into motors 159a so that the force transmitted from driving head 21 to rocker 20 through the liquid in pressure chamber 155 and through motors 159 and 159a is proportional to the pressure in port 142.

The front face of driving head 21 engages a spacer block 175 (Figs. 5 and 20) the front face of which is engaged by a hold-up block 176. Blocks 175 and 176 are rigidly secured to each other and to head 21 and substantially form parts of head 21 but are made separately therefrom for convenience in manufacture. As shown in Figs. 5 and 23, block 176 has a plurality of hold-up motors 177 (three being shown) arranged therein at one side of shaft 5 and an equal number of hold-up motors 178 arranged therein at the other side of shaft 5. Hold-up motors 177 and 178 react against an annular abutment 179 which is carried by end head 2 and extends around shaft 5.

Hold-up motors 177 and 178 are alike and, as shown in Fig. 5, each includes a cylinder 180 which is formed in block 176, a hollow piston 181 which is fitted in cylinder 180 and has a spherical outer end, an annular sealing member or shoe 182 which is arranged between abutment 179 and the spherical outer end of piston 181, and a spring 183 which is arranged within piston 181 and urges piston 181 against shoe 182 and shoe 182 against abutment 179. The mating surfaces of abutment 179 and shoe 182 are made flat and smooth and the mating surfaces of shoe 182 and the head end of piston 181 are made spherical and smooth to provide therebetween joints which are substantially liquid tight but liquid will seep between piston 181 and shoe 182 and between shoe 182 and abutment 179 and form lubricating films therebetween.

When cylinder 180 is supplied with liquid under pressure, piston 181 will urge shoe 182 against abutment 179 and a hold-up force will be transmitted from abutment 179 through the liquid in cylinder 180 and through spacer block 175 to driving head 21. Shoe 182 has been mentioned as being annular but it may be of any shape providing that it has an opening extending therethrough of such size that a large part of the hold-up force is transmitted through the liquid in the opening in the shoe to thereby limit the force which is transmitted through the films of liquid between abutment 179 and shoe 182 and between shoe 182 and piston 181. When the pump is driven, driving head 21 and blocks 175 and 176 will rotate, shoes 182 will slide around upon abutment 179, and the liquid in the openings through shoes 182 will act as liquid bearings between abutment 179 and shoes 182.

In order that the several hold-up motors on each side of shaft 5 may be connected to each other, each piston 181 has an annular groove 184 formed in its outer peripheral surface and connected to its interior by suitable holes formed in its side wall. As shown in Fig. 23, the grooves 184 in the pistons 181 of hold-up motors 177 are connected to each other by a passage 185 formed in hold-up block 176, and the grooves 184 in the pistons 181 of hold-up motors 178 are connected to each other by a passage 186 formed in hold-up block 176. As shown in Fig. 5, one of the hold-up motors 177 is connected to the pressure chamber 155 in liner 153 by a passage 187 formed in spacer block 175 and in the body portion of driving head 21, and one of the hold-up motors 178 is connected to the pressure chamber 155 in

liner 154 by a passage 188 formed in spacer block 175 and in the body portion of driving head 21.

The arrangement is such that pressure will extend from the pressure chamber 155 in liner 153 through passage 187 into the cylinder 180 of one motor 177 and from that cylinder through grooves 184 and passage 185 into the cylinders 180 of the other two motors 177. Likewise, pressure will extend from the pressure chamber 155 in liner 154 through passage 188 into cylinder 180 of one motor 178 and from that cylinder through grooves 184 and passage 186 into the cylinders 180 of the other two motors 178. Since the pressure in the chamber 155 in liner 153 is the same as the pressure in the port 141 in element 22 and since the pressure in the chamber 155 in liner 154 is the same as the pressure in the port 142 in element 22 as previously explained, the pressure in motors 177 will be the same as the pressure in port 141 and the pressure in motors 178 will be the same as the pressure in port 142.

*Counterweight and stroke change mechanism*

When the pump is at zero stroke, the rear face of rocker 20 is at right angles to the axis of shaft 5 and an equal amount of the weight of rocker 20 is at opposite sides of the axis of shaft 5 so that the centrifugal forces set up in rocker 20 by rotation thereof are balanced. But when rocker 20 is swung about the axis of pins 152 from its zero strike position to effect reciprocation of pistons 11, more of the weight of rocker 20 is on one side of the axis of shaft 5 than on the other side thereof so that unbalanced centrifugal forces are set up in rocker 20 by rotation thereof.

In order to counterbalance the centrifugal forces in rocker 20, the pump is provided with a counterweight 200 which, as shown in Figs. 1, 3 and 5, extends around driving head 21 and has two arms 200a fixed to opposite sides thereof and journaled upon pins 152. When rocker 20 is swung upon pins 152 in one direction to change pump displacement, counterweight 200 is swung upon pins 152 in the opposite direction, as will presently be explained, and the mass of counterweight 200 is so proportioned and located that the unbalanced centrifugal forces in rocker 20 are neutralized by the unbalanced centrifugal forces in counterweight 200.

When rocker 20 and counterweight 200 are swung in opposite directions from their neutral position and are rotated, the unbalanced centrifugal forces in each tends to swing it farther from its neutral position. In order to relieve the stroke changing mechanism from at least a part of each of the forces tending to move rocker 20 and counterweight 200 farther from their neutral positions, the pump is provided with two tensioning devices 201 which oppose movement of counterewight 200 away from its neutral position.

As shown in Figs. 17 and 18, each device 201 includes a housing 202 which engages the flange 21a of driving head 21 and extends around an opening 203 formed in flange 21a. Housing 202 has two spring chambers 204 and 205 formed therein and a pair of lugs 206 formed thereon and extending through opening 203. Lugs 206 are connected by a pin 207 to the central portion of the front end of a lever 208 the other end of which is bifurcated and has a roller 209 arranged therein upon a pin 210. Roller 209 is fitted in an annular bushing 211 which is fixed in and extends through the radial flange of counterweight 200.

Each of spring chambers 204 and 205 has a spring 212 arranged therein between two annular spring retainers 213 and 214. Retainer 213 normally engages the front end of the spring chamber and it is engaged by a block 215 which is slidable in the front end of the spring chamber. Retainer 214 normally engages the rear end of the spring chamber and it is engaged by a block 216 which is slidable in the rear end of the spring chamber. Block 215 is connected by a bolt 217 to a clevis 218 which engages block 216 and extends through the opening 203 in driving head 21. The two clevises 218 are connected by two pins 219 to the front end of lever 208 at opposite sides of pin 207.

The arrangement is such that, when counterweight 200 is swung in one direction or the other about the axis of pins 152, rollers 209 will cause levers 208 to pivot upon pins 207. Each lever 208 will compress the spring 212 in one spring chamber against the front end of that chamber and will compress the spring 212 in the other spring chamber against the rear end of that chamber and the combined forces exerted by the springs 212 will tend to return counterweight 200 to its neutral position and will thereby oppose centrifugal forces which tend to move counterweight 200 and rocker 20 farther from their neutral positions.

The present invention is especially applicable to very large pumps in which the centrifugal forces set up in the rocker and in the counterweight are very high. When the pump is running at full stroke, the masses of the rocker and the counterweight are at their maximum radii and the centrifugal forces are so great that a stroke changing device of ordinary size could not return the rocker and the counterweight to their zero stroke positions. Even if an over-size stroke changing device were provided, it would be impossible to reduce the pump stroke if the stroke changing device should fail to operate. It therefore is highly desirable to make the tensioning devices 201 strong enough to overcome the centrifugal force moments of the rocker and the counterweight so that the stroke changing mechanism has to help the centrifugal forces to compress springs 212 during an increase in pump stroke. Then should the stroke changing mechanism fail to operate, such as by failure of the supply of power thereto, the energy stored in springs 212 would return the rocker and the counterweight to their zero stroke positions.

Rocker 20 is adapted to be swung in either direction upon the axis of pins 152 by motion transmitted thereto through two convex racks 225 (Figs. 5 and 16) which are fixed to opposite sides thereof, and counterweight 200 is adapted to be swung in the opposite direction about the axis of pins 152 by motion transmitted thereto through two concave racks 226 (Figs. 5, 15 and 16) which are fixed to opposite sides thereof in alignment with the two racks 225 respectively.

The two racks 225 and 226 on each side of shaft 5 mesh with a pinion 227 and with a pinion 228. The two pinions 227 are fixed upon opposite ends of a shaft 229 which is journaled in driving head 21 and has a pinion 230 fixed to or formed thereon. The two pinions 228 are fixed upon opposite ends of a shaft 231 which is journaled in driving head 21 and has a pinion 232 fixed to or formed thereon. Pinion 232 meshes with a pinion 233 arranged upon a shaft 234 carried by driving head 21.

Pinion 230 meshes with a rack 235 shown in Fig. 19 as being formed integral with a piston rod 236 which is slidable in driving head 21 and in hold-up block 176. Piston rod 236 has a piston 237 fixed thereon and fitted in a cylinder 238 which is formed in spacer block 175 and forms with piston 237 and rod 236 a hydraulic motor for rotating shaft 229. Pinion 233 meshes with a rack 239 shown in Fig. 19 as being formed integral with a piston rod 240 which is slidable in driving head 21 and in hold-up block 176. Piston rod 240 has a piston 241 fixed thereon and fitted in a cylinder 242 which is formed in spacer block 175 and forms with piston 241 and rod 240 a hydraulic motor for rotating shaft 231.

The arrangement is such that, when liquid is supplied to the rear ends of cylinders 238 and 242 and causes pistons 237 and 241 to move forward, shafts 229 and 231 will be rotated in a direction to cause pinions 227 and 228 to move racks 225 and rocker 20 in one direction and to move racks 226 and counterweight 200 in the opposite direction and, when liquid is supplied to the front

ends of cylinders 238 and 242 and causes pistons 237 and 241 to move rearward, shafts 229 and 231 will be rotated in the opposite direction and thereby reverse the movements of rocker 20 and counterweight 200.

Liquid for operating motors 236—238 and 240—242 is supplied thereto under the control of a pilot valve 250 which, as shown in Fig. 20, is arranged within spacer block 175. Liquid is supplied to pilot valve 250 under the control of a selector valve 251 which, as shown in Fig. 23, is arranged within hold-up block 176.

As shown in Fig. 24, pilot valve 250 is provided with two end heads or pistons 252 and 253 and with two intermediate heads or pistons 254—255 and is fitted in the bore of a sleeve 256 which is arranged within spacer block 175. Sleeve 256 has two annular grooves or ports 257 and 258 formed in the wall of its bore and normally covered, respectively, by pistons 254 and 255 which have been shown as being of the same width as the ports so that the ports are partially opened in response to a slight movement of valve 250.

Port 257 communicates with the rear or right ends of cylinders 238 and 242 through a channel 259, and port 258 communicates with the front or left ends of cylinders 238 and 242 through a channel 260. Sleeve 256 has formed in the wall thereof between ports 257 and 258 a plurality of holes 261 which communicate with a channel 262 through which motive liquid is continuously supplied to the space between pistons 254 and 255 as will presently be explained. The space between pistons 252 and 254 communicates with an exhaust channel 263 through holes 264 formed in the wall of sleeve 256, and the space between pistons 253 and 255 communicates with an exhaust channel 265 through holes 266 formed in the wall of sleeve 256.

The arrangement is such that, when pilot valve 250 is moved a very short distance downward in respect to Fig. 24, liquid can flow from channel 262 through sleeve 256 and channel 260 to the front or left ends of cylinders 238 and 242 and move pistons 237 and 241 rearward or toward the right and, when pilot valve 250 is moved a very short distance upward in respect to Fig. 24, liquid can flow from channel 262 through sleeve 256 and channel 259 to the rear or right ends of cylinders 238 and 242 and move pistons 237 and 241 forward or toward the left.

As shown in Figs. 23 and 24, selector valve 251 is fitted in a sleeve 270 which has two annular grooves or ports 271 and 272 formed in the wall of the bore thereof and which is fitted in a bore 273 formed in spacer block 176. Port 271 communicates through suitable holes in the wall of sleeve 270 with an annular groove 274 which is formed in the wall of bore 273 and is connected by a channel 275 to one of the hold-up motors 177. Port 272 communicates through suitable holes in the wall of sleeve 270 with an annular groove 276 which is formed in the wall of bore 273 and is connected by a channel 277 to one of the hold-up motors 178.

Valve 251 has a cannelure 278 formed therein intermediate its ends and two ducts 279 and 280 extending axially into it from its opposite ends to points short of cannelure 278 and then extending radially outward into communication with ports 271 and 272 respectively. Cannelure 278 communicates with channel 262 through suitable holes formed in the wall of sleeve 270. Movement of valve 251 in either direction is limited by one or the other of two stops 281 and 282 which close opposite ends of sleeve 270.

It has previously been explained that pump pressure prevails in one set of hold-up motors 177 and 178 and that supercharge pressure prevails in the other set of hold-up motors 177 and 178. When pump pressure prevails in motors 178, liquid will flow therefrom through channel 277, groove 276, port 272 and duct 280 into the end of sleeve 270 which is the upper end in respect to Fig. 24 and the liquid will move valve 251 downward in respect to Fig. 24 against stop 281 to close port 272 and to open port 271. Then liquid will flow from motors 177 through channel 275, groove 274, port 271, cannelure 278, channel 262 and holes 261 into the space between pistons 254 and 255 of pilot valve 250. When pump pressure prevails in motors 177, liquid will flow therefrom through channel 275, groove 274, port 271 and duct 279 into the end of sleeve 270 which is the lower end in respect to Fig. 24 and the liquid will move valve 251 upward in respect to Fig. 24 against stop 282 to close port 271 and to open port 272. Then liquid will flow from motors 178 through channel 277, groove 276, port 272, cannelure 278, channel 262 and holes 261 into the space between the pistons 254 and 255 of pilot valve 250. Pilot valve 250 is thus always supplied with liquid at supercharge pressure and, consequently, stroke change motors 236—238 and 240—242 are always operated by liquid at supercharge pressure.

Pilot valve 250 may be operated in any suitable manner. For the purpose of illustration, it has been shown in Fig. 20 as having its upper end in respect to the drawing in engagement with a follow-up lever 290 intermediate the ends thereof, valve 250 being held against lever 290 by centrifugal force when the pump is operating. The rear end of lever 290 is pivoted to one end of a crank 291 (Figs. 16, 20 and 21) having the other end thereof fixed upon one end of a shaft 292 which is journaled in a bearing 293 carried by driving head 21. A crank 294 has one of its ends fixed to the other end of shaft 292 and its other end provided with a roller 295 to engage an arcuate cam 296 which is fixed to rack 226. Roller 295 is held in contact with cam 296 by a spring 297 shown as being arranged between crank 291 and the annular shell $21^b$ of driving head 21.

The front end of lever 290 is urged by a spring 298 against the radially outward end of a rod 299 which is slidable in block 176 and has its inner end in engagement with the substantially horizontal arm 300 (Figs. 20 and 23) of a lever which has a bifurcated substantially vertical arm 301 and is pivoted by a pin 302 to a support 303 carried by block 176. Arm 301 straddles shaft 5 and has its radially inward ends connected by bolts 304 to a ring 305 which encircles shaft 5 and is movable longitudinally thereof to effect variations in pump displacement. Bolts 304 connect the ends of lever arm 301 to ring 305 in such a manner that the ends of arm 301 are positively moved in synchronism with ring 305 and lever 300—301 can pivot upon pin 302.

The arrangement is such that, when ring 305 is moved rearward along shaft 5, lever 300—301 will pivot upon pin 302 and will cause rod 299 to raise the front end of lever 290 which will permit pilot valve 250 to be moved radially outward by centrifugal force. Moving valve 250 outward will cause counterweight 200 and cam 296 to be swung downward in respect to Figs. 1 and 16 and cam 296 will permit spring 297 to move the rear end of lever 290 radially inward as fast as the front end of lever 290 is moved outward so that adjustment of the pump will cease as soon as movement of ring 305 ceases. Movement of ring 305 forward along shaft 5 will cause the parts to move in substantially the above described manner but in the opposite directions.

Any suitable mechanism may be employed for moving ring 305 along shaft 5 such, for example, as the mechanism shown in Figs. 5, 20 and 22. As shown, ring 305 engages the rear end of a sleeve 310 which is slidable in two bushings 311 and 312 closely fitted in end head 2. Rotation of sleeve 310 and bushing 311 is prevented in any suitable manner such as by means of a key 313 (Fig. 20) which prevents sleeve 310 from rotating in bushing 311 and a pin 314 (Fig. 5) which prevents bushing 311 from rotating in end head 2. Sleeve 310 has journaled thereon a worm wheel 315 having teeth on only a part of its outer periphery and in mesh with a worm 316 which is fixed upon a shaft 317 journaled in bearings 318 carried by end head 2. Worm wheel 315

has fixed there in a pin 319 which extends into a helical slot 320 formed in sleeve 310.

The arrangement is such that, when worm 316 is rotated in one direction or the other, worm wheel 315 will be rotated in one direction or the other and pin 319 will move along slot 320 and, since slot 320 is formed diagonally in sleeve 310, pin 319 will move sleeve 310 forward or rearward depending upon the direction of rotation of worm 316.

The driving, hold-up, counterweight and stroke changing mechanisms are not claimed herein but are claimed in application Serial No. 321,476 filed November 19, 1952. The pumping mechanism described herein may be modified in various ways without departing from the scope of the invention which is hereby claimed as follows:

I claim:

1. In a pump having an intake channel and a discharge channel the combination of a cylinder block having formed therein a plurality of cylinders and an equal number of valve bores each having a center port communicating with one of said cylinders and two end ports communicating with said intake and discharge channels respectively, a piston fitted in each cylinder, piston operating means for effecting intake and discharge strokes of said pistons, a main valve fitted in each of said bores to control communication between said center port and said end ports, valve actuating means driven in unison with said piston operating means for causing each main valve to connect a cylinder to said channels alternately and so timed that each main valve connects a cylinder to said discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said discharge channel, and a check valve arranged in each of said passages to permit flow of liquid therethrough from a cylinder to said discharge channel and to prevent flow in the opposite direction.

2. In a pump having an intake channel and a discharge channel the combination of a stationary cylinder block having formed therein a plurality of cylinders and an equal number of valve bores each having a center port communicating with one of said cylinders and two end ports communicating with said intake and discharge channels respectively, a piston fitted in each cylinder, piston operating means for effecting intake and discharge strokes of said pistons, a main valve fitted in each of said bores to control communication between said center port and said end ports, valve actuating means driven in unison with said piston operating means for causing each main valve to connect a cylinder to said channels alternately and so timed that each main valve connects a cylinder to said discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said discharge channel, and a check valve arranged in each of said passages to permit flow of liquid therethrough from a cylinder to said discharge channel and to prevent flow in the opposite direction.

3. In a pump having an intake channel and a discharge channel the combination of a stationary cylinder block having a plurality of cylinders arranged therein in at least one circular row and parallel to each other, a piston fitted in each cylinder, piston operating means for effecting intake and discharge strokes of said pistons, said block having formed therein adjacent to each of said cylinders a valve bore having a center port communicating with that cylinder and two end ports communicating with said intake and discharge channels respectively, a main valve fitted in each of said bores to control communication between said center port and said end ports, valve actuating means driven in unison with said piston operating means for causing each main valve to connect a cylinder to said channels alternately and so timed that each main valve connects a cylinder to said discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said discharge channel, and a check valve arranged in each of said passages to permit flow of liquid therethrough from a cylinder to said discharge channel and to prevent flow in the opposite direction.

4. In a pump having an intake channel and a discharge channel the combination of a stationary cylinder block having a plurality of cylinders arranged therein, a piston fitted in each cylinder, a drive shaft, piston operating means driven from said shaft for effecting intake and discharge strokes of said pistons, said block having formed therein adjacent to each of said cylinders a valve bore having a center port communicating with that cylinder and two end ports communicating with said intake and discharge channels respectively, a main valve fitted in each of said bores to control communication between said center port and said end ports, valve actuating means driven from said shaft for causing each main valve to connect a cylinder to said channels alternately and so timed that each main valve connects a cylinder to said discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said discharge channel, and a check valve arranged in each of said passages to permit flow of liquid therethrough from a cylinder to said discharge channel and to prevent flow in the opposite direction.

5. In a pump having an intake channel and a discharge channel the combination of a cylinder block having formed therein a plurality of cylinders and an equal number of valve bores each having a center port communicating with one of said cylinders and two end ports communicating with said intake and discharge channels respectively, a piston fitted in each cylinder, piston operating means for effecting intake and discharge strokes of said pistons, a main valve fitted in each of said bores to control communication between said center port and said end ports, valve actuating means driven in unison with said piston operating means for causing each main valve to connect a cylinder to said channels alternately and so timed that each main valve connects a cylinder to said discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said discharge channel, a check valve arranged in each of said passages to permit flow of liquid therethrough from a cylinder to said discharge channel and to prevent flow in the opposite direction, and variable displacement constant pressure pump for supplying liquid to said cylinders and capable of supplying liquid thereto at a rate at least as great as the rate at which liquid is discharged from said cylinders by said pistons.

6. In a pump having an intake channel and a discharge channel the combination of a cylinder block having formed therein a plurality of cylinders and an equal number of valve bores each having a center port communicating with one of said cylinders and two end ports which function as intake and discharge ports and communicate with said intake and discharge channels respectively, a main valve fitted in each of said bores to control communication between said center port and said end ports, a piston fitted in each cylinder, piston operating means for effecting intake and discharge

strokes of said pistons, valve actuating means driven in unison with said piston operating means for causing each main valve to connect a cylinder to said discharge channel during the discharge stroke of the piston in that cylinder and to connect that cylinder to said intake channel during the greater portion of the intake stroke of that piston so that said intake port is closed during the first part of the intake stroke of that piston, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said intake channel, and an intake check valve arranged in each of said passages to permit liquid to flow therethrough from said intake channel and to prevent flow in the opposite direction.

7. In a pump having an intake channel and a discharge channel the combination of a cylinder block having formed therein a plurality of cylinders and an equal number of valve bores each having a center port communicating with one of said cylinders and two end ports which function as intake and discharge ports and communicate with said intake and discharge channels respectively, a main valve fitted in each of said bores to control communication between said center port and said end ports, a piston fitted in each cylinder, piston operating means for effecting intake and discharge strokes of said pistons, valve actuating means driven in unison with said piston operating means for causing each main valve to connect a cylinder to said discharge channel during the discharge stroke of the piston in that cylinder and to connect that cylinder to said intake channel during the greater portion of the intake stroke of that piston so that said intake port is closed during the first part of the intake stroke of that piston, said cylinder block also having formed therein a plurality of passages each communicating with one of said cylinders and with said intake channel, and an intake check valve arranged in each of said passages to permit liquid to flow therethrough from said intake channel and to prevent flow in the opposite direction, and variable displacement constant pressure pump for supplying liquid to said cylinders and capable of supplying liquid thereto at a rate at least as great as the rate at which liquid is discharged from said cylinders by said pistons.

8. In a pump having an intake channel and a discharge channel the combination of a stationary cylinder block having a plurality of cylinders arranged therein in at least one circular row and parallel to each other, a piston fitted in each cylinder, a drive shaft, piston operating means driven from said shaft for effecting intake and discharge strokes of said pistons, said block having formed therein adjacent to each of said cylinders a valve bore having a center port communicating with that cylinder and two end ports communicating with said intake and discharge channels respectively, a main valve fitted in each of said bores to control communication between said center port and said end ports, valve actuating means driven from said shaft for causing each main valve to connect a cylinder to said discharge channel only during an intermediate portion of the discharge stroke of the piston in that cylinder and to connect that cylinder to said intake channel only during an intermediate portion of the intake stroke of that piston so that said valve is closed during the end portions of both strokes of that piston, said block having formed therein a plurality of discharge passages each connecting one of said cylinders to said discharge channel and a plurality of intake passages each connecting one of said cylinders to said intake channel, a check valve arranged in each of said discharge passages with its outlet toward said discharge channel, and a check valve arranged in each of said inlet passages with its inlet toward said inlet channel.

9. A reversible pump comprising a housing having two main channels and an auxiliary channel arranged therein, said main channels being interchangeable as intake and discharge channels, pumping mechanism arranged within said housing and including a plurality of pistons and cylinders and means for effecting intake and discharge strokes of said pistons, a mechanically actuated main valve associated with each cylinder for connecting that cylinder first to one and then to the other of said main channels to enable said pistons to discharge liquid into one and to be supplied with liquid from the other of said main channels, means driven in unison with said pumping mechanism for operating said main valves, means for adjusting said pumping mechanism to divert the liquid discharged by said pistons from one to the other of said main channels, each of said main valves being adapted to connect the cylinder associated therewith to the main channel which at that time is the discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, a discharge check valve associated with each cylinder and having its inlet connected to that cylinder and its outlet connected to said auxiliary channel to enable the piston in that cylinder during the first part of its discharge stroke to discharge liquid through said check valve into said auxiliary channel, and a selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said auxiliary channel to said other main channel.

10. A reversible pump comprising a housing having two main channels and an auxiliary channel arranged therein, said main channels being interchangeable as intake and discharge channels, pumping mechanism arranged within said housing and including a plurality of pistons and cylinders and means for effecting intake and discharge strokes of said pistons, a mechanically actuated main valve associated with each cylinder for connecting that cylinder first to one and then to the other of said main channels to enable said pistons to discharge liquid into one and to be supplied with liquid from the other of said main channels, means driven in unison with said pumping mechanism for operating said main valves, means for adjusting said pumping mechanism to divert the liquid discharged by said pistons from one to the other of said main channels, each of said main valves being adapted to connect the cylinder associated therewith to the main channel which at that time is the discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, a discharge check valve associated with each cylinder and having its inlet connected to that cylinder and its outlet connected to said auxiliary channel to enable the piston in that cylinder during the first part of its discharge stroke to discharge liquid through said check valve into said auxiliary channel, a selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said auxiliary channel to said other main channel, a source from which liquid is supplied to said cylinders, and a second selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said source to said one channel.

11. A reversible pump comprising a housing having two main channels and an auxiliary channel arranged therein, said main channels being interchangeable as intake and discharge channels, pumping mechanism arranged within said housing and including a plurality of pistons and cylinders and means for effecting intake and discharge strokes of said pistons, a mechanically actuated main valve associated with each cylinder for connecting that cylinder first to one and then to the other of said main channels to enable said pistons to discharge liquid into one and to be supplied with liquid from the other of said main channels, means driven in unison with said pumping mechanism for operating said main valves, means for adjusting said pumping

mechanism to divert the liquid discharged by said pistons from one to the other of said main channels, each of said main valves being adapted to connect the cylinder associated therewith to the main channel which at that time is the discharge channel only after the piston in that cylinder has made a predetermined part of its discharge stroke, a discharge check valve associated with each cylinder and having its inlet connected to that cylinder and its outlet connected to said auxiliary channel to enable the piston in that cylinder during the first part of its discharge stroke to discharge liquid through said check valve into said auxiliary channel, a selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said auxiliary channel to said other main channel, an auxiliary pump for supplying liquid to said cylinders and capable of supplying liquid thereto at a rate at least as great as the rate at which liquid is discharged from said cylinders by said pistons, and a second selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said auxiliary pump to said one channel.

12. A reversible pump comprising a housing having two main channels and an auxiliary channel arranged therein, said main channels being interchangeable as intake and discharge channels, pumping mechanism arranged within said housing and including a plurality of pistons and cylinders and means for affecting intake and discharge strokes of said pistons, a mechanically actuated main valve associated with each cylinder for connecting that cylinder first to one and the to the other of said main channels to enable said pistons to discharge liquid into one and to be supplied with liquid from the other of said main channels, means driven in unison with said pumping mechanism for operating said main valves, means for adjusting said pumping mechanism to divert the liquid discharged by said pistons from one to the other of said main channels, each of said main valves being adapted to connect the cylinder associated therewith to a main passage only during an intermediate portion of a stroke of the piston in that cylinder so that said main valve is closed during the end portions of both strokes of that piston, a discharge check valve associated with each cylinder and having its inlet connected to the cylinder and its outlet connected to said auxiliary channel to enable the piston in the cylinder during the first part of its discharge stroke to discharge liquid through said check valve into said auxiliary channel, a selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said auxiliary channel to said other main channel, a source from which liquid is supplied to said cylinders, an intake check valve associated with each cylinder and having its outlet connected to that cylinder and its inlet connected to said source to permit liquid to flow into that cylinder from said source during the first part of the intake stroke of the piston in that cylinder, and a second selector valve operable in response to the liquid discharged by said pistons being diverted from one to the other of said main channels for automatically connecting said source to said one channel.

13. A pump comprising a housing having a drive shaft mounted therein and two main channels arranged therein, a plurality of cylinders arranged in said housing in a circular row concentric with said shaft, a piston fitted in each cylinder, a wobble plate driven by said shaft for effecting intake and discharge strokes of said pistons, said housing having formed therein adjacent to each of said cylinders a valve bore having a center port connected to the adjacent cylinder and two end ports connected to said two main channels respectively, a piston valve fitted in each of said bores to control communication between said center port and said end ports and to connect the adjacent cylinder to said main channels alternately, a second wobble plate driven by said shaft and connected to said valves to effect reciprocation thereof in timed relation to the strokes of said pistons in response to rotation of said shaft, said piston valves being so constructed that each valve connects a cylinder to a main channel only after the piston in the cylinder has made a part of a stroke, and a plurality of passages arranged in said housing with each passage communicating with one of said main channels and with one of said cylinders and has arranged therein a discharge check valve through which liquid can be discharged from the cylinder into a main channel during the first part of a discharge stroke of the piston in that cylinder.

14. A pump according to claim 13 in which said housing has formed therein a plurality of passages each of which communicates with one of said main channels and with one of said cylinders and has arranged therein an intake check valve through which liquid can flow into that cylinder during the first part of an intake stroke of the piston in that cylinder.

15. A pump according to claim 13 in which said piston valves are so constructed that each valve connects one of said cylinders to one or the other of said main channels during only an intermediate portion of each stroke of the piston in that cylinder and is closed during the end portions of the strokes of that piston and which has an auxiliary channel in addition to said main channels, said housing having formed therein a plurality of passages each of which communicates with one of said cylinders and with said auxiliary channel, a discharge check valve arranged in each of said passages to enable the piston in the cylinder communicating with that passage to discharge liquid therefrom through said check valve into said auxiliary channel during the end portions of its discharge strokes, and a selector valve responsive to the pressure in one main channel exceeding the pressure in the other main channel for connecting said auxiliary channel to the main channel containing the higher pressure.

16. A pump according to claim 15 and including a source for supplying liquid to said cylinders, a selector valve responsive to the pressure in one of said main channels exceeding the pressure in the other main channel for connecting said source to the main channel containing the lower pressure, said housing having formed therein a plurality of passages each of which communicates with said source and with one of said cylinders, and an intake check valve arranged in each of said passages to prevent flow through that passage from the cylinder communicating therewith and to permit liquid to flow therethrough from said source to that cylinder during the end portions of the intake strokes of the piston in that cylinder.

References Cited in the file of this patent

UNITED STATES PATENTS

| | | |
|---|---|---|
| 956,016 | Woerner | Apr. 26, 1910 |
| 1,137,877 | Manly et al | May 4, 1915 |
| 2,288,768 | Zimmermann | July 7, 1942 |
| 2,433,222 | Huber | Dec. 23, 1947 |
| 2,553,655 | Herman et al | May 22, 1951 |
| 2,608,933 | Ferris | Sept. 2, 1952 |
| 2,619,041 | Born | Nov. 25, 1952 |
| 2,653,543 | Mott | Sept 29, 1953 |
| 2,661,700 | Towler | Dec. 8, 1953 |

FOREIGN PATENTS

| | | |
|---|---|---|
| 956,823 | France | 1949 |