

April 23, 1935.

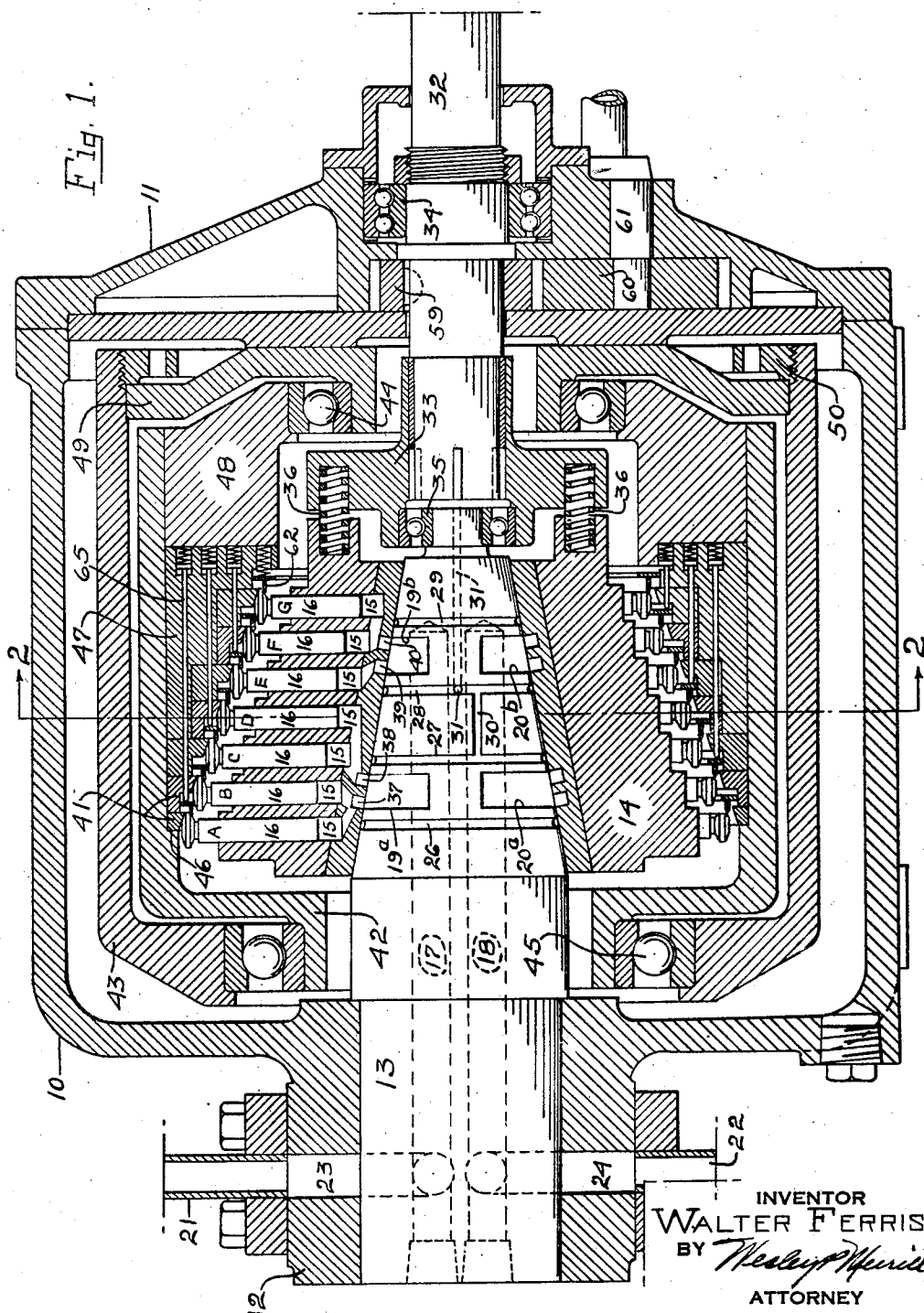
W. FERRIS

1,998,984

PUMP OR MOTOR

Filed Nov. 27, 1933

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April 23, 1935.

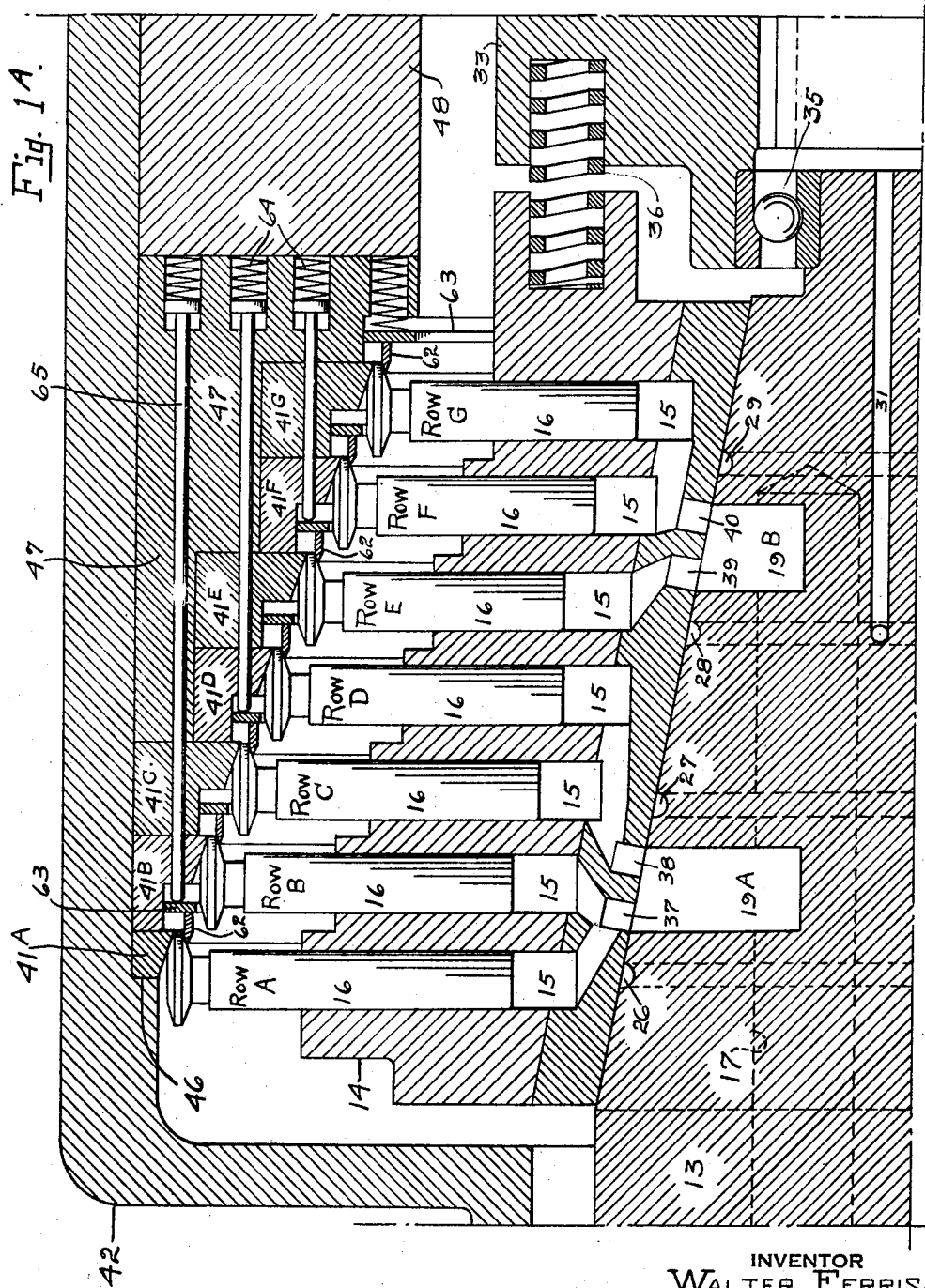
W. FERRIS

1,998,984

PUMP OR MOTOR

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5 Sheets-Sheet 2



INVENTOR
WALTER FERRIS.
BY *Walter Ferris*
ATTORNEY

April 23, 1935.

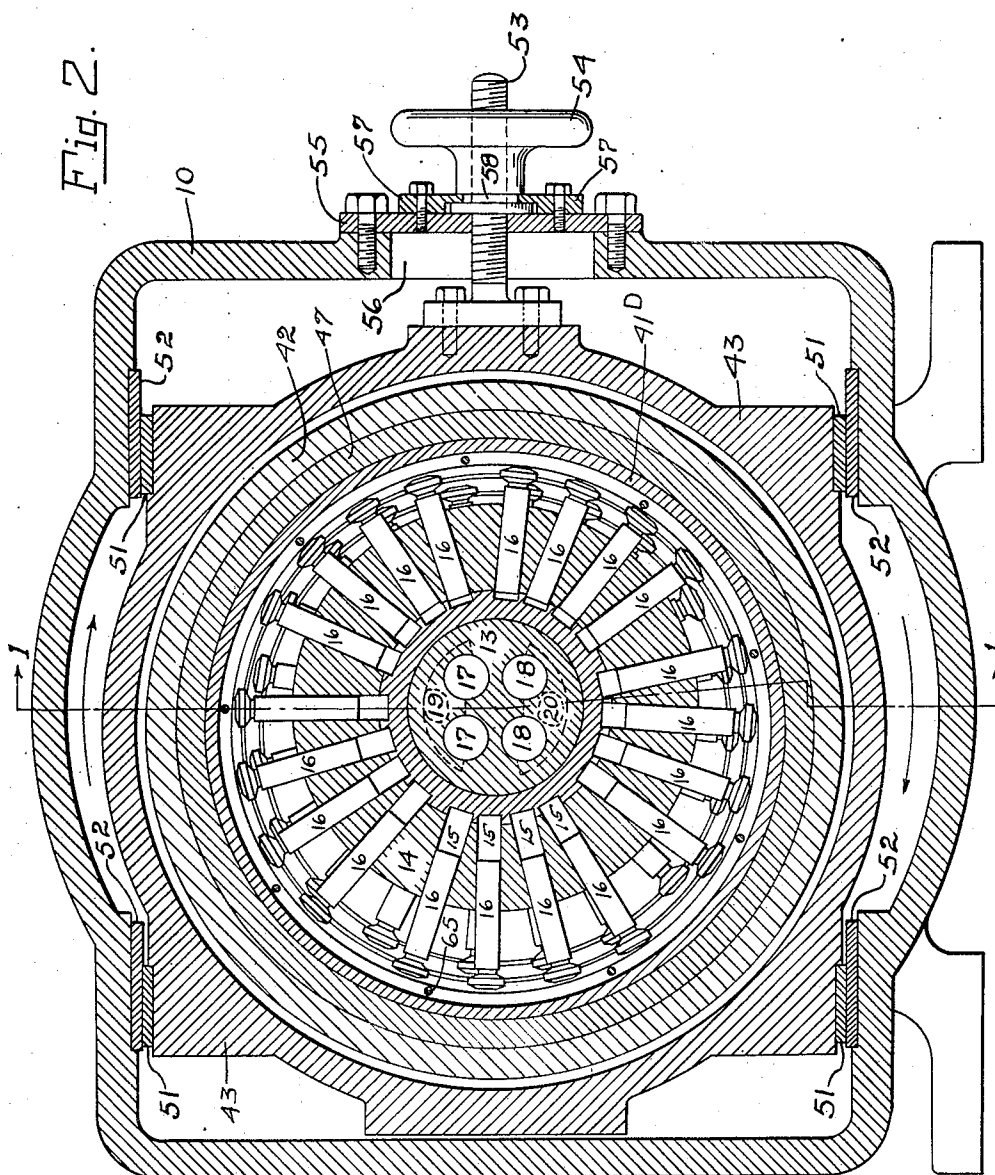
W. FERRIS

1,998,984

PUMP OR MOTOR

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5 Sheets-Sheet 3



INVENTOR
WALTER FERRIS.
BY *Wesley Merritt*
ATTORNEY

April 23, 1935.

W. FERRIS

1,998,984

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Filed Nov. 27, 1933

5. Sheets-Sheet 4

INVENTOR
WALTER F. FERRIS.
BY *Thelma P. Ferris*
ATTORNEY

April 23, 1935.

W. FERRIS

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PUMP OR MOTOR

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5 Sheets-Sheet 5

Fig. 5.

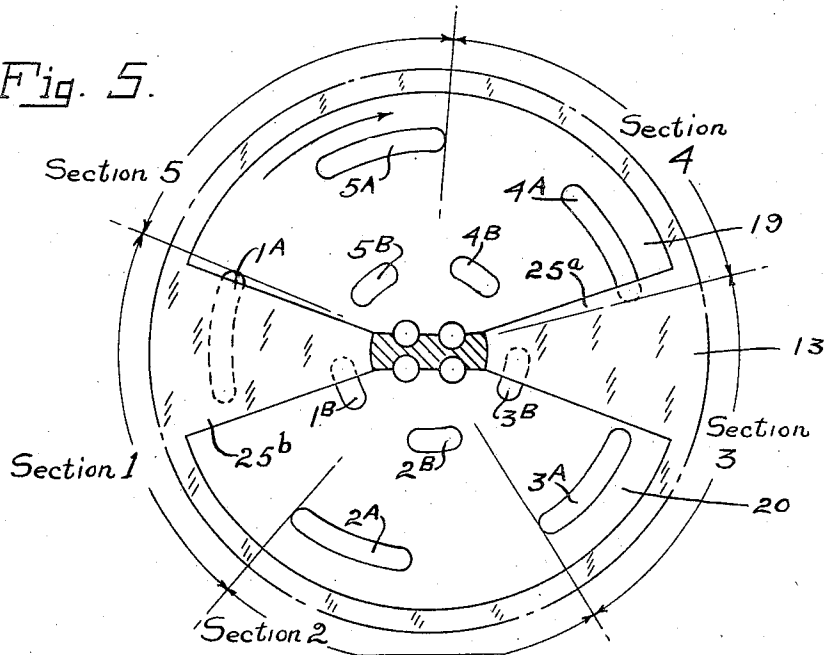
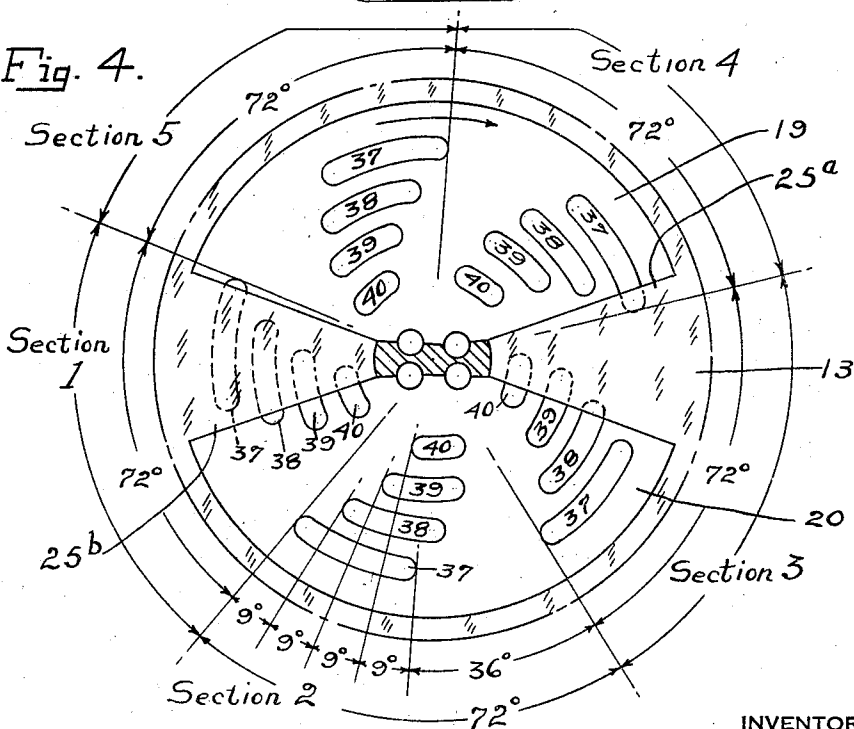


Fig. 4.



INVENTOR
WALTER FERRIS.
BY *Walter Ferris*
ATTORNEY

UNITED STATES PATENT OFFICE

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PUMP OR MOTOR

Walter Ferris, Milwaukee, Wis., assignor to The
Oilgear Company, Milwaukee, Wis., a corpora-
tion of Wisconsin

Application November 27, 1933, Serial No. 699,847

20 Claims. (Cl. 103—161)

This invention relates to hydraulic machines of the type having radial pistons and cylinders arranged in a cylinder barrel which rotates upon a central valve or pintle through which liquid flows to and from the cylinders, such as the hydraulic machine disclosed in my copending application, Serial No. 662,219, filed March 23, 1933 of which this application is a continuation as to matters common to both applications.

The machine will function as a pump whenever its cylinder barrel is driven from a suitable source of power and it will function as a motor whenever liquid is delivered under pressure to its cylinders. For the purpose of explanation, the machine will be described herein as a pump but it is to be understood that the invention is equally applicable to a motor and that the term "pump" as used herein is intended to define either a pump or a motor.

The central valve or pintle has intake and discharge passages formed therein and terminating, respectively, in an intake port and a discharge port which are ordinarily arranged diametrically opposite each other and separated by a narrow section generally designated as a "bridge". Each cylinder communicates with these two ports alternately as the cylinder barrel rotates and is open to each port through a substantial part of a half revolution of the cylinder barrel.

When a pump is delivering liquid under pressure, a cylinder passing from the intake to the discharge port is substantially filled with liquid at a low pressure and, as it begins to pass off the bridge and to open to the discharge port, the pressure of the liquid in the cylinder is suddenly raised by the high pressure in the discharge port, thereby suddenly loading the piston and its driving mechanism and producing a shock and a resultant noise.

Conversely, when a cylinder passes from the discharge port to the intake port, it contains liquid under high pressure and, as it begins to pass off the bridge and to open to the intake port, the pressure in the cylinder and the strain upon the piston and its driving mechanism are suddenly released, thereby producing a shock and a resultant noise.

These shocks, caused by each cylinder opening to the intake and discharge ports, react upon the pintle at its bridge and produce what are generally known as bridge reactions. If a pump is provided with an even number of equally spaced cylinders, one cylinder will open to one port at the same time that another cylinder opens to another port and the bridge reactions resulting from the

two cylinders opening at the same time will be simultaneous and in the same direction.

In order to reduce the bridge reactions and the resultant noise, it has been common practice to provide a pump with an odd number of equally spaced cylinders so that but one cylinder opens to a port at any given instant.

When a pump has been developed which is reasonably quiet at a given maximum pressure and a given maximum speed, a pump of larger capacity may be produced either by increasing the diameter of the cylinders or by providing the pump with more cylinders of the same diameter. The first method increases the shock and noise proportionately to the square of the cylinder diameter and the second method has a similar effect if two or more of the cylinders open to a port at the same instant.

The present invention has as an object to provide a pump which will operate quietly and in which the bridge reactions have been reduced to a minimum.

Another object is to provide a pump which may be made in larger sizes or capacities without materially increasing either the bridge reaction or the resultant noise.

Another object is to provide a pump having a large capacity relative to its overall dimensions.

Another object is to provide a pump in which the internal leakage or slip is kept at a substantially constant minimum.

Another object is to provide a pump which is compact and efficient.

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

According to the invention in one of its aspects, the pump is provided with a plurality of cylinders which communicate with the pintle ports through cylinder ports, a plurality of cylinder ports open successively to one pintle port and then another plurality of cylinder ports open successively to the other pintle port, and no two cylinder ports open at the same instant.

According to the invention in another aspect, the pump is provided with a cylinder barrel which rotates upon a tapered pintle and is urged toward the large end thereof by the lateral components of the pumping forces.

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

Fig. 1 is a longitudinal section taken through the pump on the irregular line I—I of Figs. 2

and 3 and showing the pistons arranged in longitudinal rows for the purpose of illustration.

Fig. 1^A is a view taken in the same plane as Fig. 1 but drawn to a larger scale.

5 Fig. 2 is a transverse section taken on the line 2—2 of Fig. 1.

Fig. 3 is a developed view of the inside of the cylinder barrel and shows the relation of the cylinder ports to the cylinders and to each other.

10 Fig. 4 is a schematic developed view of the outside of the central valve or pintle and shows the relation of the cylinder ports to each other and to the pintle ports.

Fig. 5 is a view similar to Fig. 4 but showing only two circumferential rows of cylinder ports.

The pump has its mechanism arranged within and carried by a closed casing 10 which has a removable head 11 attached to its front end and a boss 12 formed integral with its rear head or wall.

20 The boss 12 supports a valve shaft or pintle 13 which has its rear part rigidly secured in the boss 12 and its front part tapered and extending forward in the casing.

A cylinder barrel 14 is journaled upon the tapered part of the pintle 13 and provided with a plurality of radial cylinders 15 each of which has a piston 16 fitted therein.

25 Liquid flows to and from the cylinders 15 through two upper passages 17 and two lower passages 18 which are formed in the pintle 13 longitudinally thereof and communicate, respectively, at the front ends thereof with an upper pintle port 19 and a lower pintle port 20.

30 The passages 17 and 18 may be connected at the rear ends thereof to an external circuit as by means of two pipes 21 and 22 attached to the boss 12 and communicating respectively, with the passages 17 and 18 through two passages 23 and 24 formed in the boss 12.

40 Each of the pintle ports 19 and 20 may consist of two or more slots. As shown, the port 19 consists of two slots 19^a and 19^b and the port 20 consists of two slots 20^a and 20^b which are arranged, respectively, diametrically opposite the slots 19^a and 19^b.

45 Each of these slots extends from the periphery of the pintle into communication with the pintle passages 17 or 18 and is formed by removing from the pintle a segment thereof equal to a substantial part of one-half of the cross-sectional area of the pintle at that point.

50 The ports 19 and 20 are thus separated from each other by a section of metal the outer peripheral surfaces of which are generally known as bridges and which have been designated in Figs. 4 and 5 by the reference numerals 25^a and 25^b.

55 The pump shown is provided with a large number of small cylinders arranged in seven circumferential rows A, B, C, D, E, F, G and discharging through cylinder ports which are arranged in four circumferential rows as shown in Fig. 3 and as will be described hereafter.

60 The cylinder ports in two of these rows communicate with the slots 19^a and 20^b alternately and the cylinder ports in the other two rows communicate with the slots 19^b and 20^a alternately as the cylinder barrel rotates.

65 This arrangement avoids ducts of excessive length leading from the end rows of cylinders as would be necessary if each of the pintle ports consisted of a single slot and all of the cylinders communicated therewith during rotation of the cylinder barrel.

70 Also, such long ducts would contain relatively large volumes of liquid which would be com-

pressed by the pistons but not expelled into the discharge port of the pintle, and the compression of these volumes of liquid and the following re-expansion thereof when the cylinder ports opened to the intake port would reduce the efficiency of the pump.

Further, it would be impossible to provide long ducts leading from cylinders in outside rows and under cylinders in intermediate rows to a central port without materially increasing the distance 10 from the surface of the pintle to the bottoms of the cylinders, thereby increasing the diameters of the cylinder barrel and the pump and further increasing the volume of liquid which is compressed but not ejected into the pintle discharge 15 port.

When the pump is operating, liquid seeps from the high pressure pintle port between the cylinder barrel and the pintle and forms therebetween a lubricating film the pressure of which 20 varies in accordance with variations in pump pressure and diminishes as the distance from the high pressure port increases.

The pressure in the lubricating film tends to separate the cylinder barrel from the high pressure side of the pintle and thereby tends to cause it to bear more heavily upon the low pressure side of the pintle.

In order to limit the high pressure area in the lubricating film, the pintle is provided with four limit grooves 26, 27, 28 and 29 which extend 30 around the pintle adjacent the ends of the pintle port slots, the slots 19^a and 20^a being arranged between the grooves 26 and 27 and the slots 19^b and 20^b being arranged between the grooves 28 and 29.

The area between the grooves 26 and 27 and the area between the grooves 28 and 29 constitute narrow valve seats upon which the lubricating film adjacent the high pressure pintle 40 port has a high pressure whenever the pump is delivering liquid at high pressure.

The valve seats, or high pressure areas between the grooves 26 and 27 and between the grooves 28 and 29, are made relatively narrow so that 45 the outward force exerted by the film upon the cylinder barrel and tending to separate it from the high pressure side of the pintle does not exceed the inward force which is transmitted from the pistons to the cylinder barrel through the liquid in the cylinders, thereby preventing the cylinder barrel from binding and from bearing heavily against the low pressure side of the pintle.

The film covering the area at the rear of the groove 26 and the film covering the area at the 55 front of the groove 29 have very low pressures for the reason that the liquid can escape from the ends of the cylinder barrel.

The film covering the area between the grooves 27 and 28 is also kept at a low pressure as by 60 connecting the grooves 27 and 28 to each other by a longitudinal groove 30 and draining this area through a small drain channel 31 which extends axially inward from the front end of the pintle and then radially outward into communication with the groove 28.

65 These low pressure areas function primarily as bearing surfaces which are adequately lubricated by liquid which escapes from the high pressure pintle port and passes the limit grooves.

70 The cylinder barrel is rotated upon the pintle 13 by a drive shaft 32 which has a circular driver 33 splined upon its inner or rear end. The drive shaft 32 extends through the front head 11 in which it is supported by a ball bearing 34 and 75

its inner end is supported by a bearing 35 carried by the front end of the pintle 13 and fitted in the end of the driver 33.

The driver 33 is connected to the cylinder barrel 14 by flexible driving connections such as a plurality of helical springs 36 which are arranged in suitable recesses formed in the driver and in the cylinder barrel. The springs 36 are capable of transmitting a high driving torque from the driver to the cylinder barrel and will deflect to compensate for slight misalignment of parts and thereby allow the cylinder barrel to be accurately seated upon the pintle.

In order to facilitate manufacturing, the cylinder barrel ordinarily consists of two sections rigidly secured to each other, the outer section having the cylinders formed therein and the inner section having the cylinder ports formed therein. The inner section is ordinarily provided on its inside with a thin liner of bearing metal, such as bronze, but this characteristic has not been illustrated as the use of such metals in bearings is well known.

As previously explained, the cylinders 15 are arranged in circumferential rows, that is, rows which extend around the cylinder barrel in planes transverse to the pintle axis, and the cylinders communicate with cylinder ports which are also arranged in circumferential rows.

The pump shown has its cylinders arranged in seven rows A, B, C, D, E, F, G (Figs. 1 and 3) and with twenty cylinders in each row or a total of 140 cylinders which communicate with twenty cylinder ports which are arranged in four circumferential rows.

The outer (Fig. 3) or rear (Fig. 1) row contains five ports 37 each of which serves four cylinders in row A and four cylinders in row B, the next row contains five ports 38 each of which serves four cylinders in row C and four cylinders in row D, the next row contains five ports 39 each of which serves four cylinders in row E and two cylinders in row F, and the inner or front row contains five ports 40 each of which serves two cylinders in row F and four cylinders in row G.

The capacity of the pump may be varied by varying the number of rows of cylinders and it may be further varied by varying the number of cylinders in each row.

The pistons in each row of cylinders are urged inward during one-half revolution of the cylinder barrel by a thrust ring 41 which is arranged around the cylinder barrel eccentric thereto and is differentiated from the other thrust rings by adding as an exponent to its reference numeral 41 the reference letter of the row of pistons with which it is associated.

Each piston 16 is provided at its outer end with an enlarged head having beveled or arcuate outer and under faces, and each thrust ring 41 has its inner face beveled and in contact with the heads of the pistons in one of the circumferential rows, the head of each piston contacting a thrust ring upon a single point or spot arranged forward of the piston axis and, when the pump is in operation, all pumping forces are transmitted from the thrust ring to the piston through this point or spot.

This spot or point of contact between the thrust ring and the piston head is arranged at such a distance from the piston axis, and the bevels of the thrust ring and of the piston head are such that the lateral components of the pumping forces land upon the wall of the cylinder

between the ends thereof so that the piston has a uniform bearing in its cylinder and undue and irregular wear of the cylinder wall is avoided.

When the pump is delivering liquid under pressure, it has an internal leakage or slip which consists primarily of small volumes which pass across the bridge from the discharge port to the intake port and other small volumes which pass along the pintle and escape from the ends of the cylinder barrel and through the drain channel 31. The pump also has an apparent slip which is due primarily to compression of the liquid and deflection of certain pump parts.

The slip of a pump varies in accordance with variations in both the pressure and the temperature of the liquid for the reason that, with a given film thickness, the film will move more rapidly under a high pressure than under a low pressure and, due to variations in the viscosity of the liquid, the film will flow more readily and rapidly when hot than when cold.

When the pump is in operation, pressure prevails in the lubricating film between the cylinder barrel and the pintle, as previously explained, and this pressure acts upon the projected areas of the tapered coacting surfaces of the cylinder barrel and the pintle and urges the cylinder barrel toward the small end of the pintle with a force which varies as the pump pressure varies, thereby tending to increase the clearance between the cylinder barrel and the pintle and increase the slip of the pump.

Since the point of contact between the head of each piston and its thrust ring is in front of the piston axis, the cylinder barrel is urged rearward toward the large end of the pintle by a force equal to the sum of the lateral components of the pumping forces transmitted through all of the pistons, thereby tending to decrease the clearance between the cylinder barrel and the pintle and decrease the slip of the pump.

In order to keep the slip of the pump as low as possible and thereby maintain pump delivery substantially constant, the pump parts are so proportioned that the sum of the above mentioned forces which urge the cylinder barrel toward the large end of the pintle exceed the total force which tends to move the cylinder barrel toward the small end of the pintle.

This excess force urges the cylinder barrel toward the large end of the pintle and causes it to seat firmly upon the pintle and, since both the pumping force transmitted through the pistons and the pressure in the lubricating film are substantially proportional to pump pressure, this excess force is also substantially proportional to pump pressure and the cylinder barrel is pressed ever more firmly against the pintle as pump pressure increases, thereby reducing the thickness of the lubricating film in response to an increase in pressure and also in response to a decrease in the viscosity of the liquid.

The slip of the pump is thus maintained at the minimum consistent with sufficient lubrication at all operating pressures and temperatures, thereby keeping the net delivery of the pump approximately constant.

The thrust rings 41 are arranged within and restrained from radial or axial movement by a rotatable drum 42 which is supported within a cradle 43 upon two ball bearings 44 and 45 arranged, respectively, at its front and its rear ends and carried by the cradle 43.

The thrust rings 41 are held against movement relative to the drum 42 and are arranged therein

with their inner or bearing faces at substantially the same radial distance from the tapered surface of the pintle 13.

The thrust rings 41^A, 41^B and 41^C are fitted in the drum 42 in engagement with each other and with the thrust ring 41^A in engagement with a shoulder 46 formed in the wall of the drum 42.

The other thrust rings are fitted in an annular filler block 47 which is fitted within the drum 42 and shaped upon its inside to hold the several rings in contact with each other. All of the thrust rings are thus held against movement relative to the drum 42.

The filler block 47 is engaged upon its front end by an annular bearing block 48 which is fitted within the drum 42 and has the outer race of the bearing 44 fitted within its front end.

The bearing 44 is of the radial thrust type and has its inner race fitted upon the hub of an end plate 49 which is fitted within the front end of the cradle 43 and retained in position therein by a threaded ring 50 which is threaded into the front end of the cradle 43.

The drum 42, the thrust rings 41, the filler block 47 and the bearing block 48 combine to form a thrust member which urges the pistons inward during rotation of the cylinder barrel and which is rotated upon the bearings 44 and 45 in synchronism with the cylinder barrel by frictional contact of the piston heads with the thrust rings 41.

When the pump is delivering liquid, the axis of the drum 42 is offset from the axis of the cylinder barrel in order that the pistons may move outward during one-half of a revolution of the cylinder barrel to permit the cylinders to be filled with liquid and in order that the pistons will be forced inward during the next half-revolution of the cylinder barrel to eject liquid from the cylinders.

This outward and inward movement of the pistons causes each piston head to move at a variable linear speed which varies in accordance with the distance between it and the axis of rotation of the cylinder barrel, while the thrust ring with which that piston head is in contact moves at a constant linear speed. Therefore, during one part of a revolution, each piston head moves faster than a given point on the thrust ring with which it is in contact and it moves slower than that point during another part of a revolution.

Since each piston head is in contact with its thrust ring at only a single point or spot which is offset from the piston axis, this variation in the relative linear speeds of the piston head and its thrust ring causes the piston head to roll along the thrust ring and the piston to rotate in its cylinder, thereby eliminating all sliding friction between the pistons and the thrust member and also avoiding the use of the heavy cross-heads formerly employed upon the ends of pump pistons to eliminate sliding friction.

The stroke of the pump, or the length of the outward and inward movement of each piston, is proportional to the distance between the axis of the cylinder barrel and the axis of the thrust member. This distance may be fixed by securing the cradle 43 in a permanent position within the casing 10 to thereby provide a pump having a fixed stroke and constant displacement, or the cradle 43 may be adjustable, as shown in Fig. 2, to provide a pump having a variable displacement.

As shown in Fig. 2, the cradle 43 has a suitable number of slide plates 51 attached thereto and

in contact with a corresponding number of stationary slide plates 52 which are carried by the casing 10. The slide plates 51 and 52 permit the cradle to move transverse to the pintle axis in a horizontal direction but prevent it from moving transverse to the pintle axis in any other direction.

In actual practice, the pump is ordinarily provided with a hydraulically operated control for shifting the cradle 43 but, for the purpose of illustration, it is shown provided with an adjusting screw 53 which is fastened to the cradle 43 and has a handwheel 54 threaded thereon for manual adjustment of the pump.

The handwheel 54 is restrained from axial movement in one direction by the end of its hub abutting a plate 55, which is fastened to the casing 10 and closes an opening 56 therein, and it is restrained from axial movement in the opposite direction by one or more bearing plates 57 which are fastened to the plate 55 and extend into an annular groove 58 formed in the hub of the wheel.

When the cylinder barrel 14 is rotated in the direction of the arrows and the thrust member has its axis offset toward the left from the axis of the cylinder barrel as shown in Fig. 2, the pistons in the lower half of the cylinder barrel will move outward to permit their cylinders to be filled with liquid through the pintle port 20, the pistons in the upper half of the cylinder barrel will move inward and eject liquid from their cylinders through the pintle port 19, and the volume of liquid discharged per revolution will be proportional to the distance between the axis of the thrust member and the axis of the cylinder barrel.

Rotation of the handwheel 54 to move the cradle 43 toward the right will gradually reduce the stroke and the volumetric delivery of the pump until the cradle arrives at its central or neutral position, that is, when the axis of the thrust member coincides with the axis of the cylinder barrel, at which time pump delivery is zero.

Further movement of the cradle 43 toward the right will cause the pump to be reversed, that is, to discharge through the port 20 and at a rate corresponding to the distance which it is moved from its central or neutral position. The pump may also be reversed by reversing the direction of rotation of the cylinder barrel, in which case the pump will discharge through the pintle port 20 when the cradle is at the left of its neutral position and through the pintle port 19 when the cradle is at the right of its neutral position.

When the cylinder barrel is being rotated at its normal operating speed, centrifugal force tends to move the pistons on the intake side outward, but at low speeds this is not always to be relied upon for supplying liquid to the cylinders which are positively and completely filled by either delivering liquid thereto under a low pressure or by providing mechanical means for positively retracting the pistons.

Liquid may be supplied to the cylinders by an ordinary type of gear pump which is arranged in the front head 11 and has its driving gear 59 fixed upon the drive shaft 32 and its driven gear 60 arranged upon a stub shaft 61 carried by the front head 11. The gear pump provides an auxiliary source of pressure liquid for operating controls and the like, and it may be incorporated in the pump for this purpose even when mechanical means are provided for retracting the pistons.

The mechanical means for retracting the pistons is shown as including a number of retraction rings 62 one of which is arranged alongside each circumferential row of pistons and in contact with the under face of each piston head in that row. The retraction rings are flexible and resilient in order that each ring may deflect slightly into a non-circular shape as the piston heads in contact therewith move relatively to the thrust ring with which they are in contact and yet maintain a continuous outward pressure on each piston head.

Each retraction ring 62 is engaged at its front edge by a flat pressure ring 63 which is urged rearward by a number of springs 64 to keep the rear edge of the retraction ring in contact with the under faces of all of the piston heads in its row of pistons.

The springs 64 react against the rear end of the bearing block 48 and are arranged in recesses which are formed in the front end of the filler block 47 and arranged in concentric circles.

The springs 64 in the recesses in the innermost circle act directly upon the front pressure ring 63 but the other springs 64 act upon the other pressure rings through push rods 65 which extend through the filler block 47 and through one or more of the thrust rings 41, the push rod in engagement with one pressure ring being of a different length than the push rod in engagement with any other pressure ring.

The retraction rings 62 hold the piston heads in contact with the thrust rings and thus positively move the pistons on the intake side of the pump outward and enable them to draw the liquid into their cylinders during each revolution of the cylinder barrel.

If the machine is to be employed as a pump, it may be provided with either a gear pump or with mechanical means for retracting its pistons, or with both. If the machine is to be employed as a motor, it does not require either a gear pump or mechanical means for retracting its pistons.

For the purpose of explanation and as shown in Fig. 3, the cylinder barrel has been divided into five sections 1, 2, 3, 4 and 5 each of which contains one port of each row and the cylinders connected thereto. That is, it contains one port 37, one port 38, one port 39 and one port 40 and the cylinders served by those ports, or a total of 28 cylinders.

The cylinders connected to each cylinder port are so arranged relatively thereto and to each other that the net delivery therefrom is zero when that port is covered by one of the bridges 25^a or 25^b during which time a part of the cylinders pass dead center so that the movements of the pistons therein is reversed. In other words, liquid is transferred from one or more cylinders to one or more other cylinders connected to the same cylinder port during the time that that port is covered by the bridge and the effect of the outward moving pistons is neutralized by the inward moving pistons.

Each of sections 1, 2, 3, 4 and 5 correspond to one cylinder of a five-cylinder pump, such as the pump shown in my Patent No. 1,619,200, and if all of the cylinders in each section opened to a pintle port at the same time, the bridge reactions and the resultant noise would be the same as in a prior pump of the same capacity.

However, the cylinder ports are so arranged that but one cylinder port opens to a pintle port at any given instant, thereby keeping the bridge reactions and the resultant noise at a minimum.

The arrangement of cylinder ports to produce this result is best shown in Figs. 4 and 5, Fig. 4 being a schematic developed view of the outside of the pintle 13 with the cylinder ports superimposed thereon, and Fig. 5 being a similar but simplified view showing only two rows of cylinder ports.

Referring first to Fig. 5, it will be noted that there are ten cylinder ports arranged in two circumferential rows of five ports each and that each of sections 1, 2, 3, 4 and 5 contain two ports one of which is arranged in the outer row and the other in the inner row.

If the two ports in each section were arranged in alinement axially of the pintle, both would open to a pintle port at the same instant, that is, the pump would still be a single phase pump even though it is provided with two cylinder ports in each section.

If all of its ports were equally spaced, that is, if the ports in one row were advanced ahead of the ports in the other row by one-half the angular distance between the centers of adjacent ports, the effect would be to produce a ten section pump which would still be single phase and have the added disadvantage that one port would open to the pintle intake port at the same instant that another port opened to the pintle discharge port, and the total bridge reactions would be as great as a five-section single phase pump of the same volumetric capacity.

In the present invention, however, the cylinder ports in one section open successively to one pintle port, immediately thereafter the cylinder ports in another section open successively to the other pintle port, and no two cylinder ports open to any pintle port at any given instant.

This is accomplished by positioning the cylinder ports in each succeeding row such a small angular distance behind the corresponding cylinder ports in the preceding row that all of the cylinder ports in one section have their leading ends, or the ends which first open to a pintle port, arranged within one-half of the section angle and, in order that the bridge reactions may be distributed uniformly throughout each revolution of the cylinder barrel, the cylinder ports are so positioned that the leading end of each cylinder port in each succeeding row is spaced from the leading end of the corresponding cylinder port in the preceding row by an angular distance equal to one-half the section angle divided by the number of rows of ports.

For example, the pump shown has its cylinder barrel divided into five equal sections each of which extends through an angle of 72°. If the cylinder barrel had two rows of cylinder ports as shown in Fig. 5, each section would contain two ports one of which would be spaced from the other port by an angular distance determined by dividing one-half of the section angle into two equal parts. Hence, the two ports in each section would be spaced 18° apart to split the phase of the pump.

The ports in one section of Fig. 5 are practically the same as the ports in any other section but, in order to differentiate therebetween, the ports in the outer and inner rows have been designated, respectively, by the letters A and B added to the number of the section in which the same are arranged.

With the cylinder ports arranged as shown in Fig. 5, rotation of the cylinder barrel will cause the outer and inner ports in one section to open successively to one pintle port and then the outer

and inner ports in another section to open successively to another port. As shown, all ports in sections 2 and 3 and port 1^B in section 1 are open to the pintle intake port 20, all ports in sections 4 and 5 and port 1^A in section 1 are open to the pintle discharge port 19.

Assuming that the cylinder barrel is rotating in the direction of the arrow, port 1^A has just opened to the port 19 and port 1^B will open next so that the shock caused by the opening of port 1^A has passed before the shock caused by the opening of port 1^B occurs.

After port 1^B opens to pintle port 19, ports 4^A and 4^B will open successively to pintle port 20, then ports 2^A and 2^B will open successively to pintle port 19, then ports 5^A and 5^B will open successively to pintle port 20, then ports 3^A and 3^B will open successively to pintle port 19, and the ports in each section will continue in this manner to open successively and at uniform intervals first to one pintle port and then the other but no two ports will open at the same instant.

Consequently, the shocks and noise caused by the several cylinder ports opening to the pintle ports are distributed uniformly throughout each revolution of the cylinder barrel and are kept at a minimum.

If the cylinder barrel is provided with a greater number of rows of piston ports, one-half of the section angle is divided into a correspondingly greater number of parts to determine the split phasing of the pump. For example, if the cylinder barrel is provided with four rows of cylinder ports as shown in Figs. 1 to 4, each section will contain four cylinder ports which will be spaced 9° apart as shown in Fig. 4, this angular distance being determined by dividing one-half of the section angle by four.

With the cylinder ports arranged in this manner, all four ports in one section will open successively to one pintle port and then all four ports in another section will open successively to another pintle port but no two pintle ports will open at any given instant.

Assuming that the ports are in the position shown in Fig. 4 and that the cylinder barrel is rotating in the direction of the arrow, port 37 in section 1 has just opened to the pintle port 19, ports 38, 39 and 40 in section 1 will open successively to the port 19 as the cylinder barrel continues to rotate, and port 40 in section 1 will open to port 19 before port 37 in section 4 opens to pintle port 20.

Immediately thereafter, the cylinder ports in section 4 will open successively to the pintle port 20 and then the cylinder ports in section 2 will open successively to the pintle port 19. The cylinder ports in succeeding sections will open successively to the two pintle ports alternately and, since the sections are equally spaced and since the cylinder ports in each section are spaced the same angular distance apart, the bridge reactions are distributed uniformly throughout each revolution of the cylinder barrel.

A pump or motor constructed in accordance with the present invention is efficient in operation and will operate quietly even when made in large sizes.

The pump described herein is susceptible of various modifications without departing from the scope of the invention as hereafter claimed.

The invention is hereby claimed as follows:

1. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve

member and provided with a plurality of cylinders having ports to communicate with said valve ports alternately as said cylinder member rotates and so arranged that but one cylinder port opens to a valve port at any given instant and that a plurality of cylinder ports open successively to one of said valve ports and then another plurality of cylinder ports open successively to the other valve port, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

2. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinders having ports to communicate with said valve ports alternately as said cylinder member rotates, said cylinder ports being arranged in a plurality of circular rows and so positioned in respect to each other that a plurality of cylinder ports open successively to one valve port and then another plurality of cylinder ports open successively to the other valve port but only one cylinder port opens to a valve port at any given instant, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

3. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinders having ports to communicate with said valve ports alternately as said cylinder member rotates, said cylinder ports being arranged in a plurality of circular rows and so positioned in respect to each other that but one cylinder port opens to a valve port at any given instant and that a plurality of cylinder ports open successively to one of said valve ports and then another plurality of cylinder ports open successively to the other valve port, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

4. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinders having ports to communicate with said valve ports alternately as said cylinder member rotates and arranged in a plurality of circular rows with a port in one row forming with a port in each of the other rows a group of ports which have the leading ends thereof arranged within one-half or less of the angular distance between adjacent groups and open successively to said valve ports as said cylinder member rotates, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

5. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinder ports to communicate with said valve ports alternately as said cylinder member rotates and so arranged that but one cylinder port opens to a valve port at any given instant and that a plurality of cylinder ports open successively to one of said valve ports and then another plurality of cylinder ports open successively to the other valve port, a greater number of cylinders than cylinder ports arranged in said cylinder member with a plurality of cylinders communicating with a sin-

gle cylinder port, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

6. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinder ports to communicate with said valve ports alternately as said cylinder member rotates, said cylinder ports being arranged in a plurality of circular rows and so positioned in respect to each other that a plurality of cylinder ports open successively to one valve port and then another plurality of cylinder ports open successively to the other valve port but only one cylinder port opens to a valve port at any given instant, a greater number of cylinders than cylinder ports arranged in said cylinder member with a plurality of cylinders communicating with a single cylinder port, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

7. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinder ports to communicate with said valve ports alternately as said cylinder member rotates, said cylinder ports being arranged in a plurality of circular rows and so positioned in respect to each other that but one cylinder port opens to a valve port at any given instant and that a plurality of cylinder ports open successively to one of said valve ports and then another plurality of cylinder ports open successively to the other valve port, a greater number of cylinders than cylinder ports arranged in said cylinder member with a plurality of cylinders communicating with a single cylinder port, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

8. A split phase pump, comprising a valve member having intake and discharge ports, a rotatable cylinder member bearing upon said valve member and provided with a plurality of cylinder ports to communicate with said valve ports alternately as said cylinder member rotates and arranged in a plurality of circular rows with a port in one row forming with a port in each of the other rows a group of ports which have the leading ends thereof arranged within one-half or less of the angular distance between adjacent groups and open successively to said valve ports as said cylinder member rotates, a greater number of cylinders than cylinder ports arranged in said cylinder member with a plurality of cylinders communicating with a single cylinder port, pistons arranged in said cylinders, and means for causing reciprocation of said pistons during rotation of said cylinder member.

9. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports to register with said pintle ports alternately as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder to reciprocate therein and provided with a beveled outer end, a thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the outer end of

each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, and means for rotating said cylinder barrel.

10. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports to register with said pintle ports alternately as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder to reciprocate therein and provided with a beveled head upon its outer end, a thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the head of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for rotating said cylinder barrel, and means engaging said piston heads upon the under sides thereof to urge the same outward during rotation of said cylinder barrel.

11. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports to register with said pintle ports alternately as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder to reciprocate therein and provided with a beveled outer end, a rotatable thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the outer end of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for supporting said thrust member, and means for rotating said cylinder barrel.

12. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports to register with said pintle ports alternately as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder to reciprocate therein and provided with a beveled head upon its outer end, a rotatable thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the head of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for supporting said thrust member, means for rotat-

ing said cylinder barrel, and means engaging said piston heads upon the under sides thereof to urge the same outward during rotation of said cylinder barrel.

13. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports to register with said pintle ports alternately as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder to reciprocate therein and provided with a beveled head upon its outer end, a rotatable thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the head of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for rotating said cylinder barrel, resilient members engaging said piston heads upon the under sides thereof to urge the same outward during rotation of said cylinder barrel, and means for urging each resilient member toward the piston heads engaged thereby.

14. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports so arranged that but one cylinder port opens to a pintle port at any given instant and a plurality of cylinder ports open successively to one pintle port and then another plurality of cylinder ports open successively to the other pintle port, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder and provided with a beveled outer end, a thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the outer end of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, and means for rotating said cylinder barrel.

15. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports so arranged that but one cylinder port opens to a pintle port at any given instant and a plurality of cylinder ports open successively to one pintle port and then another plurality of cylinder ports open successively to the other pintle port, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder and provided with a beveled head upon its outer end, a thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the head of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward

the large end of said pintle with a force proportional to pump pressure, means for rotating said cylinder barrel, and means engaging said piston heads upon the under sides thereof to urge said pistons outward during rotation of said cylinder barrel.

16. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with cylinder ports so arranged that but one cylinder port opens to a pintle port at any given instant and a plurality of cylinder ports open successively to one pintle port and then another plurality of cylinder ports open successively to the other pintle port, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder and provided with a beveled outer end, a rotatable thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the outer end of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for rotating said cylinder barrel, and means for supporting said thrust member.

17. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with a plurality of cylinder ports arranged in a plurality of circumferential rows with a port in one row forming with a port in each of the other rows a group of ports which have the leading ends thereof arranged within one-half or less of the angular distance between adjacent groups and open successively to said pintle ports as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder and provided with a beveled outer end, a thrust member arranged around said cylinder barrel eccentric thereto and provided with a beveled face in contact with the outer end of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, and means for rotating said cylinder barrel.

18. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with a plurality of cylinder ports arranged in a plurality of circumferential rows with a port in one row forming with a port in each of the other rows a group of ports which have the leading ends thereof arranged within one-half or less of the angular distance between adjacent groups and open successively to said pintle ports as said cylinder barrel rotates, radial cylinders arranged in circumferential rows in said cylinder barrel with a plurality of cylinders in each of a plurality of rows communicating with each of said cylinder ports, a piston fitted in each cylinder and provided with a beveled outer end, a thrust member arranged around said cylinder barrel eccentric

thereto and provided with a beveled face in contact with the outer end of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit

5 forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, and means for rotating said cylinder barrel.

10 19. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with a plurality of cylinder ports arranged
15 in a plurality of circumferential rows with a port in one row forming with a port in each of the other rows a group of ports which have the leading ends thereof arranged within one-half or less
20 of the angular distance between adjacent groups and open successively to said pintle ports as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with
25 said cylinder ports, a piston fitted in each cylinder and provided with a beveled head upon its outer end, a thrust member arranged around said cylinder barrel eccentric thereto and provided with
30 a beveled face in contact with the head of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for rotat-

ing said cylinder barrel, and means engaging said piston heads upon the under sides thereof to urge said pistons outward during rotation of said cylinder barrel.

20. A pump, comprising a pintle tapering toward its front end and provided with intake and discharge ports and passages, a cylinder barrel fitted upon said pintle to rotate thereon and provided with a plurality of cylinder ports arranged in a plurality of circumferential rows
10 with a port in one row forming with a port in each of the other rows a group of ports which have the leading ends thereof arranged within one-half or less of the angular distance between
15 adjacent groups and open successively to said pintle ports as said cylinder barrel rotates, radial cylinders arranged in said cylinder barrel in communication with said cylinder ports, a piston fitted in each cylinder and provided with a beveled outer end, a rotatable thrust member arranged around said cylinder barrel eccentric
20 thereto and provided with a beveled face in contact with the outer end of each piston only at a point forward of the piston axis whereby rotation of said cylinder barrel will cause said member to
25 transmit forces to said pistons to operate the same and the lateral components of said forces will urge said cylinder barrel toward the large end of said pintle with a force proportional to pump pressure, means for rotating said cylinder
30 barrel, and means for supporting said thrust member.

WALTER FERRIS.