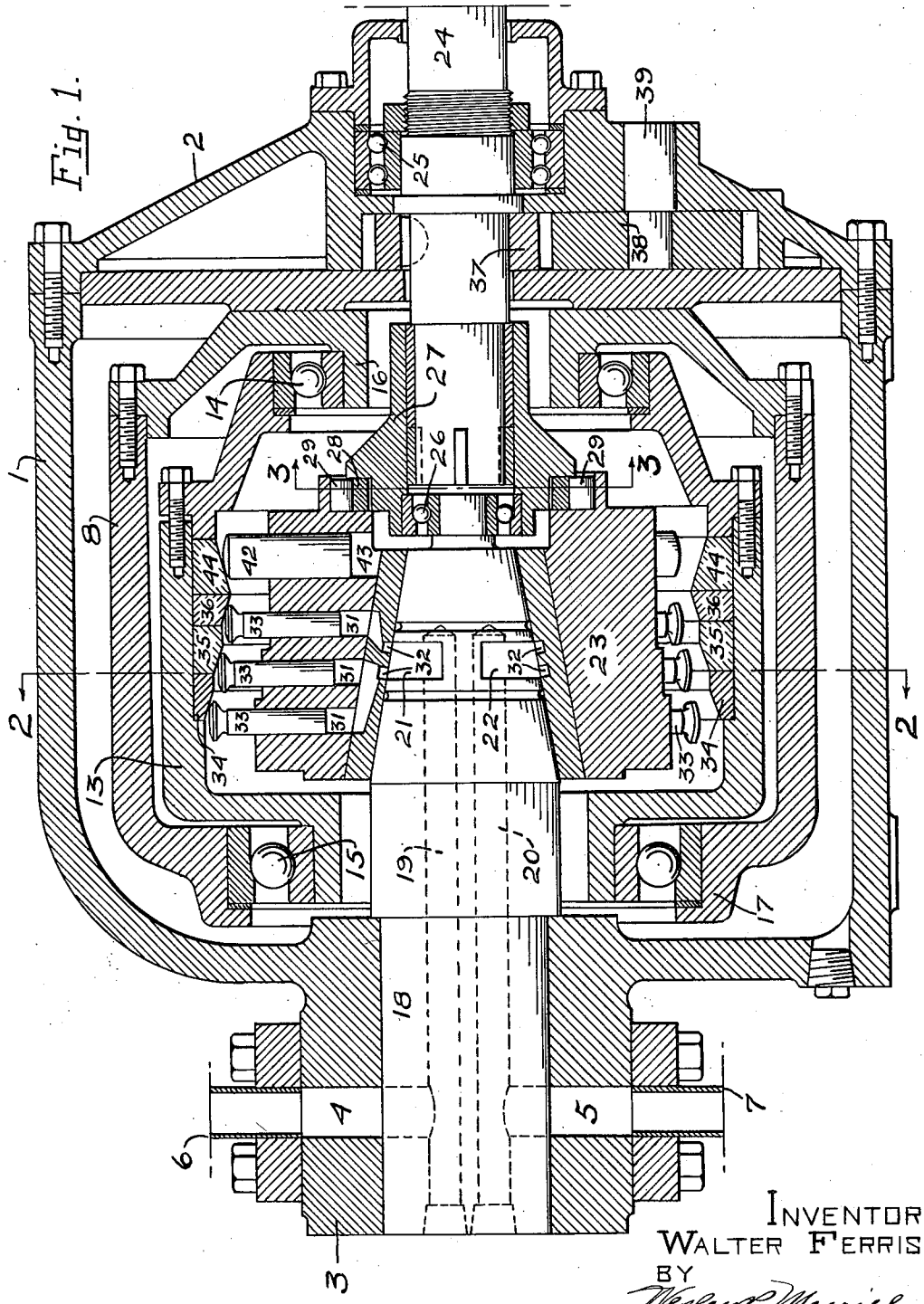
March 31, 1936. W. FERRIS 2,035,647

PUMP OR MOTOR

Filed Nov. 3, 1934 2 Sheets-Sheet 1

Fig. 1.



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Filed Nov. 3, 1934 2 Sheets-Sheet 2

Fig. 2.

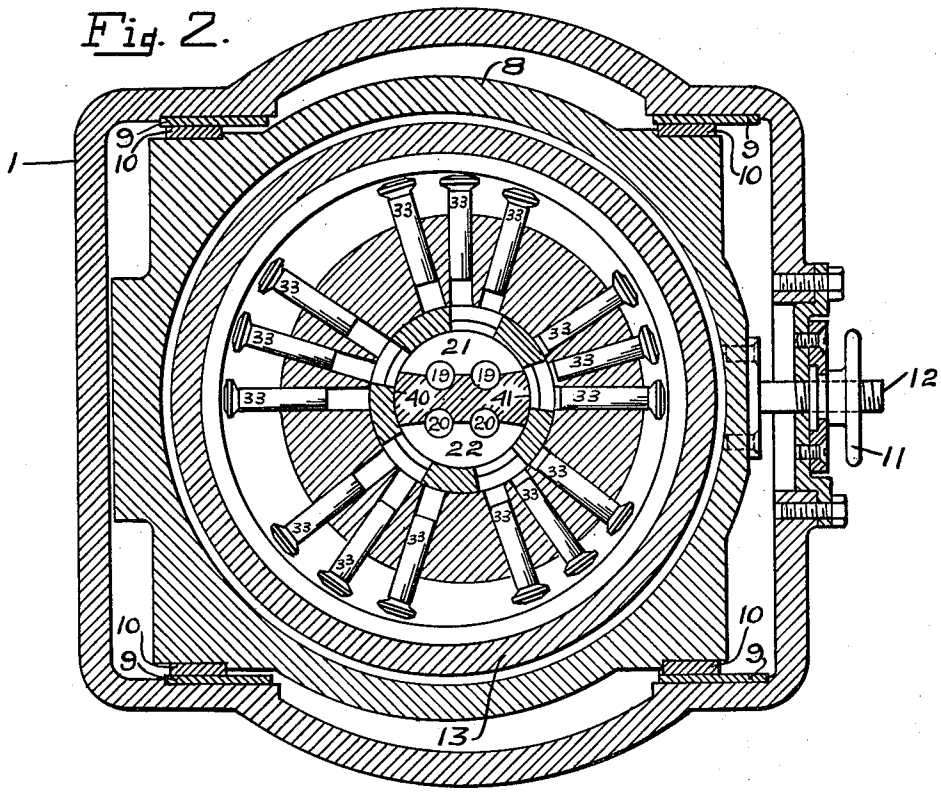


Fig. 4.

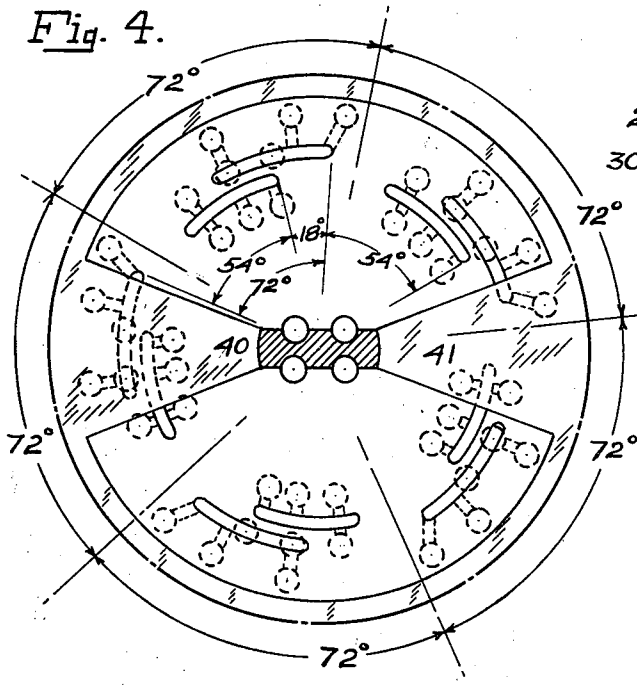
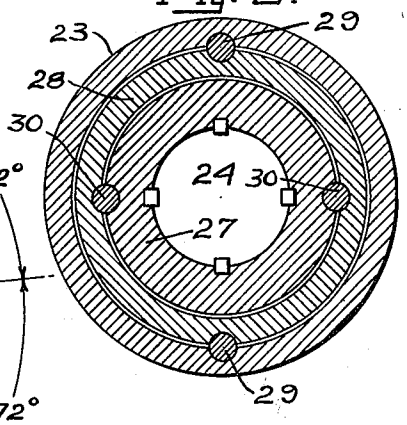


Fig. 3.



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UNITED STATES PATENT OFFICE

2,035,647

PUMP OR MOTOR

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Application November 3, 1934, Serial No. 751,300

16 Claims. (Cl. 103—161)

This invention relates to hydraulic machines of the type in which a cylinder barrel is provided with radial cylinders and rotates upon a central valve shaft or pintle through which liquid flows to and from the cylinders, a piston is fitted in each cylinder and provided with a beveled contact face upon its outer end, and a cylindrical thrust member is arranged around the cylinder barrel eccentric thereto and provided with an inclined reaction surface which engages the contact face of each piston at one side of the piston axis whereby rotation of the cylinder barrel causes pumping forces to be transmitted from the thrust member to the piston and the lateral components of those forces tend to move the cylinder barrel along the pintle, such as the hydraulic machines disclosed in my copending applications Serial No. 662,219, filed March 23, 1933 and Serial No. 699,847, filed November 27, 1933 Patent No. 1,998,984, of which this application is a continuation in part.

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.

When the cylinder barrel is rotating, each piston is urged radially outward against the inclined reaction surface on the thrust member by centrifugal force the lateral component of which tends to move the cylinder barrel along the pintle in the same direction that it is urged by the lateral components of the pumping forces.

If the machine is provided with a tapered pintle and is run at a constant speed, as is customary in the operation of volumetric pumps, it may be so designed that the sum of the lateral components of the pumping and centrifugal forces will be just sufficient to maintain the correct pressure between the bearing surfaces of the cylinder barrel and the pintle and thereby keep the internal leakage or slip of the pump at a substantially constant minimum.

If the machine is operated at varying speeds, as would ordinarily be the case when functioning as a motor, the lateral component of the centrifugal force would vary in accordance with variations in the speed thereby varying the clearance between the bearing surfaces of the cylinder barrel and the pintle and causing the slip of the machine to increase or the cylinder barrel to tend to bind upon the pintle.

The present invention has as its object to provide a hydraulic machine of the character described with means for counteracting or balancing the lateral components of the centrifugal forces generated in its pistons.

According to the invention in its general aspect, the machine is provided with non-pumping or balancing pistons having the outer ends thereof beveled and urged by centrifugal force into contact with a reaction surface which is inclined opposite to the inclined reaction surface against which the pumping pistons bear.

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

Fig. 1 is a central longitudinal section through the pump.

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

Fig. 3 is a section taken on the line 3—3 of Fig. 1 and showing details of the universal joint which connects the drive shaft to the cylinder barrel.

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

The pump has its mechanism arranged within a casing 1 which is closed at its front end by a removable head 2 and has a boss 3 fixed to its rear wall and provided with two radial passages 4 and 5 by means of which the pump may be connected to the pipes 6 and 7 of an external hydraulic circuit.

The casing contains a cradle 8 which is restrained from forward movement by the head 2 and from vertical movement by slide plates 9 and 10 upon which the cradle may slide transversely of the casing to vary pump displacement. The cradle is ordinarily moved hydraulically but, for the purpose of illustration, it is shown as being movable by means of a handwheel 11 rotatably supported against axial movement by the side wall of the casing and threaded upon a rod 12 which is fixed to the cradle.

The cradle 8 has a cylindrical thrust member 13 arranged therein and rotatably supported at its front and rear ends upon two antifriction bearings 14 and 15 which are carried, respectively by an internal hollow hub 16 and an external hollow hub 17 fixed upon the front and rear walls of the cradle 8.

The casing 1 supports a valve shaft or pintle 18 which has its rear part rigidly secured in

the boss 3 and its front part tapered and extended through the hub 17 into the thrust member 13. The pintle 18 has two upper longitudinal passages 19 and two lower longitudinal passages 20 formed therein. The passages 19 and 20 communicate, respectively, at the rear ends thereof with the radial passages 4 and 5 in the boss 3 and at the front ends thereof with two valve ports 21 and 22 which are formed diametrically opposite each other in the tapered part of the pintle 18.

The pintle 18 has a cylinder barrel 23 journaled upon the tapered part thereof and rotated by a drive shaft 24 which is supported by two bearings 25 and 26 carried, respectively, by the front head 2 and by the front end of the pintle 18. The shaft 24 has a driver 27 splined upon the inner end thereof and connected to cylinder barrel 23 by a universal joint which permits the cylinder barrel to adjust itself upon the pintle. A suitable joint may be formed by connecting a flat ring 28 (Figs. 1 and 3) to the cylinder barrel by two diametrically opposed pins or rollers 29 and to the driver by two diametrically opposed pins or rollers 30.

The ring 28 is arranged in a circular recess in the end of the cylinder barrel and encircles a hub formed on the end of the driver, there being a slight clearance between the ring and the hub and between the ring and the periphery of the recess. Each pin 29 is loosely fitted in two complementary semicircular recesses one of which is formed in the outer periphery of the ring 28 and the other of which is formed in the cylinder barrel 23. Each pin 30 is loosely fitted in two complementary semicircular recesses one of which is formed in the inner periphery of the ring 28 and the other of which is formed in the driver 27.

The cylinder barrel 23 is provided with a plurality of radial cylinders 31 which are shown arranged in three circular rows and connected to a plurality of cylinder ports 32 which are shown arranged in two circular rows. Each cylinder port registers with the valve ports 21 and 22 alternately as the cylinder barrel rotates.

The cylinders and cylinder ports are shown as divided into five groups, each group consisting of one cylinder port in each of the two rows of ports and three cylinders in each of the three rows of cylinders.

The three cylinders in the rear row and two of the cylinders in the center row are connected to the rear cylinder port and the three cylinders in the front row and one cylinder in the center row are connected to the front cylinder port, as shown in Fig. 4.

Each cylinder port in one row is offset from the adjacent cylinder port in the other row and the several ports are so arranged that two cylinder ports open successively to one pintle port and then two other cylinder ports open successively to the other pintle port but no two cylinder ports open to any cylinder port at any given instant, as fully explained in application Patent No. 1,998,984 referred to above.

A piston 33 is fitted in each cylinder and normally has its outer end or head in engagement with the beveled inner face of one of three thrust rings 34, 35, and 36 which are fastened to the inside of the thrust member 13. The rings 34, 35, and 36 are so positioned in respect to the rear, center and front rows of cylinders that each ring engages the outer end of all pistons in one row of cylinders.

When the cylinder barrel is rotated and the axis of the thrust member 13 offset to one side of the cylinder barrel axis, the pistons may move outward during one-half revolution of the cylinder barrel and are forced inward by the thrust rings during the other half revolution to force liquid from their cylinders and cause the pump to deliver liquid in one direction. If the thrust member 13 is shifted until its axis is on the other side of the cylinder barrel axis, the pump will deliver liquid in the opposite direction.

If the machine is to be employed as a pump, the pistons may be moved outward by centrifugal force or in any other suitable manner such as by pressure created by an auxiliary pump which delivers liquid into the intake port of the pintle. As shown, a gear pump has its driving gear 37 fixed upon the drive shaft 24, its driven gear 38 arranged upon a stub shaft 39 carried by the front head 2, and both gears arranged in a suitable pump chamber formed in the front head. The gear pump is connected to the intake side of the main pump through a valve and channels not shown.

When the cylinder barrel is rotated, the thrust member 13 is rotated at substantially the same speed upon the bearings 14 and 15 by the frictional contact of the pistons with the thrust rings 34, 35 and 36.

Each of the pistons 33 engages one of the rings 34, 35 and 36 at a single point or spot which is offset from the piston axis. In order that this spot may be offset a substantial distance from the piston axis, each piston is ordinarily provided upon its outer end with a head of greater diameter than the body of the piston. The piston head has a beveled or arcuate but non-spherical bearing face which engages the inclined reaction surface on a thrust ring at a point offset forward from the piston axis whereby, during operation of the pump, the piston head rolls along the thrust ring and the pumping force is transmitted from the thrust ring to the piston at an angle to the piston axis and the lateral component of the pumping force urges the cylinder barrel toward the large end of the pintle, as fully explained in the applications referred to above.

Assuming that the thrust member 13 has its axis offset to the left of the cylinder barrel axis and that the cylinder barrel is rotating in a clockwise direction as viewed in Fig. 2, the pistons above the horizontal centerline of the pintle will be moving inward and the pistons below that line will be moving outward so that liquid will be ejected into the pintle port 21 from all of those cylinders whose ports 32 are open to that pintle port and liquid will be drawn from the pintle port 22 into all of those cylinders whose ports 32 are open to that pintle port.

When each piston crosses the horizontal centerline of the pintle, it will be at dead center and there will be but little reciprocating movement of any of the pistons in those cylinders whose ports 32 are covered by the bridges 40 and 41 (Fig. 4) which separate the pintle ports 21 and 22 from each other.

In order that this slight piston movement may not create a partial vacuum or tend to compress the liquid in those cylinders whose ports are covered by the bridges 40 and 41, the cylinders connected to each cylinder port 32 are so arranged in respect to that port that liquid is transferred from one or more cylinders to one or more other cylinders and the net delivery from the cylinders connected to that port is zero when that

port is covered by the bridge **40** or **41** during which time a part of the cylinders pass dead center so that the movement of the pistons therein is reversed. In other words, the cylinders connected to each cylinder port are so positioned that the total increment of displacement of the outward moving pistons is exactly equal to the total decrement of displacement of the inward moving pistons during the time that that port is covered by the bridge **40** or the bridge **41**.

As the cylinder barrel rotates, each piston is forced outward by centrifugal force against the beveled face of the thrust ring **34**, **35** or **36** which reacts upon the beveled end of the piston at the same angle to the piston axis as the pumping force acts thereon so that the lateral component of the centrifugal force augments the lateral component of the pumping force.

If the pump is provided with a tapered pintle, the inner beveled faces of the thrust rings **34**, **35** and **36** are inclined inward toward the small end of the pintle taper and the point of contact between the piston head and its thrust ring is on the side of the piston axis toward the small end of the pintle taper, as shown in Fig. 1, so that the lateral components of the pumping and centrifugal forces urge the cylinder barrel toward the large end of the taper and hold it up on the pintle.

The effect of these lateral components upon the cylinder barrel is counteracted in part by the pressure of a film of liquid which is maintained between the cylinder barrel and the pintle at all times. The pressure of this film acts upon the projected radial area of the bearing surface of the cylinder barrel and urges it toward the small end of the pintle.

If the cylinder barrel is to be rotated at a constant speed, so that the lateral components of the centrifugal force will remain constant, the steepness of the pintle taper and the distance which the point of contact on the pistons is offset from the piston axis may be so proportioned that at a given low pump pressure the sum of the forces which urges the cylinder barrel toward the large end of the pintle exceeds by a small margin the forces which urge it toward the small end of the pintle.

The preponderance of force urging the cylinder barrel toward the large end of the pintle causes the cylinder barrel to bear uniformly upon the film of liquid between the cylinder barrel and the pintle, the viscosity of the liquid determining the clearance between the cylinder barrel and the pintle. If the liquid should become thinner, as by being heated, this preponderance of force would move the cylinder barrel along the pintle to decrease the clearance therebetween and thereby prevent the slip of the pump from increasing in response to a decrease in the viscosity of the liquid.

When the pump pressure increases, the sum of the forces which urge the cylinder barrel toward the large end of the pintle exceeds the opposing force by a greater margin and reduces the clearance between the cylinder barrel and the pintle, thereby preventing the slip of the pump from increasing as the pump pressure increases.

If the speed of the cylinder barrel should vary, the sum of the forces which urge the cylinder barrel toward the large end of the pintle would vary for the reason that the centrifugal force acting through pistons **33** would vary. Therefore, if the machine is to function as a motor or for any reason is to be operated at different speeds, the effect of the lateral components of the centrifugal force upon the cylinder barrel should be neutralized. This may be accomplished by providing the cylinder barrel with one or more non-pumping balancing pistons **42** to counteract the lateral components of the centrifugal forces acting through the pumping pistons **33**.

Each piston **42** is fitted in a cylinder **43** which is formed in the cylinder barrel but which is at no time open to the pintle port **21** or to the pintle port **22**.

Each cylinder **43** has its inner end open to the atmosphere to permit the piston **42** therein to reciprocate freely, and it may be so arranged that its open end lies radially outward from the end of the pintle so that liquid which seeps from between the cylinder barrel and the pintle and is carried radially outward by centrifugal force may enter the open end of the cylinder to lubricate the piston **42** and the cylinder wall.

The outer end of each piston **42** is beveled or arcuate and in contact with the inner beveled face of a thrust ring **44** which is arranged in the thrust member **13** concentric with the thrust rings **34**, **35** and **36** and has its inner face inclined inward toward the large end of the pintle taper and in contact with the beveled end of each piston **42** at a point offset from the piston axis toward the large end of the pintle.

The contact face upon the outer end of each balancing piston **42** is preferably of the same character as the contact faces on the heads of the pumping pistons **33**. That is, it is arcuate but nonspherical and so shaped that the thrust ring **44** may engage it upon a single spot of substantial area in all positions of the piston throughout a complete revolution of the cylinder barrel.

During rotation of the cylinder barrel, the pistons **42** are urged radially outward by centrifugal force against the inner face of the thrust ring **44** which reacts upon the beveled end of each piston at an angle to its axis so that the lateral components of the centrifugal force tend to move the cylinder barrel toward the small end of the pintle.

Each balancing piston **42** is ordinarily cylindrical and provided upon its outer end or head with an arcuate bearing surface to engage the inclined bearing surface on the thrust ring **44** at a point offset from the piston axis so that each piston **42** rotates in its cylinder whenever the cylinder barrel is rotating and the axis of the thrust ring **44** is offset from the cylinder barrel axis, thereby maintaining a uniform film of liquid between the piston and the wall of its cylinder.

The total mass of the pistons **42**, the distance which the point of contact between each piston **42** and the thrust ring **44** is offset from the piston axis, and the bevel of the inner face of the thrust ring **44** is such that the sum of the lateral components of the centrifugal force acting through the pistons **42** is equal and opposite to the sum of the lateral components of the centrifugal force acting through the pistons **33**.

With this arrangement the cylinder barrel is not affected by centrifugal force and the heads of the pumping pistons **33** and the inner faces of the thrust rings **34**, **35** and **36** may be so proportioned in respect to the pintle taper that, at a given low pump pressure, the lateral components of the pumping forces will hold the cylinder barrel firmly seated upon the pintle. Then,

when the pump pressure increases or the viscosity of the liquid decreases, the clearance between the cylinder barrel and the pintle will be decreased to prevent variation in the slip of the pump, as previously explained.

If, instead of directing liquid to and from the cylinders 31 through the pintle, the cylinders 31 were connected to cylinder ports arranged in one end of the cylinder barrel and that end of the cylinder barrel engaged a flat valve plate of the type employed in axial pumps, such as the pump disclosed in the Williams Patent No. 893,558 the cylinder barrel would be urged against the valve plate by the lateral components of the pumping and the centrifugal forces. By providing this type of pump with balancing pistons, the lateral components of the centrifugal forces generated in the balancing pistons would oppose the lateral components of the centrifugal forces generated in the pumping pistons, and if these components were equal, the cylinder barrel would be held against the valve plate solely by the lateral components of the pumping forces.

The invention herein set forth is susceptible of various modifications and adaptations without departing from the scope thereof as hereafter claimed.

The invention is hereby claimed as follows:

1. In a pump having a rotatable cylinder barrel provided with substantially radial cylinders and a valve member through which liquid may flow to and from said cylinders and against which said cylinder barrel bears and is restrained thereby from movement in one axial direction, the combination of a piston fitted in each cylinder and provided upon its outer end with a contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge each piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution and thereby cause said pistons to pump liquid through said valve member, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of each piston at one side of the piston axis to transmit thrust to said piston whereby during rotation of said cylinder barrel the lateral component of the centrifugal force generated in each piston by rotation of said cylinder barrel tends to move said cylinder barrel axially in a direction to increase the bearing pressure between said cylinder barrel and said valve member, and means independent of said pumping pistons for generating another force to counteract the effect upon said cylinder barrel of said lateral component.

2. In a pump having a rotatable cylinder barrel provided with substantially radial cylinders and a valve member through which liquid may flow to and from said cylinders and against which said cylinder barrel bears and is restrained thereby from movement in one axial direction, the combination of a piston fitted in each cylinder and provided upon its outer end with a contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge each piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution and thereby cause said pistons to pump liquid through said valve member, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of each piston at one side of the piston axis to transmit thrust to said piston whereby during rotation of said cylinder barrel the lateral component of the centrifugal force generated in each piston by rotation of said cylinder barrel tends to move said cylinder barrel axially in a direction to increase the bearing pressure between said cylinder barrel and said valve member, and means independent of said pumping pistons for generating another centrifugal force the lateral component of which is substantially equal and opposite in direction to the lateral component of the centrifugal force generated in said pumping pistons.

3. In a pump having a rotatable cylinder barrel provided with substantially radial cylinders and a valve member through which liquid may flow to and from said cylinders and against which said cylinder barrel bears and is restrained thereby from movement in one axial direction, the combination of a piston fitted in each cylinder and provided upon its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge each piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution and thereby cause said pistons to pump liquid through said valve member, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of each piston upon a single spot offset from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in each piston a centrifugal force the lateral component of which tends to move said cylinder barrel axially in a direction to increase the bearing pressure between said cylinder barrel and said valve member, and means independent of said pumping pistons for generating another force to counteract the effect upon said cylinder barrel of said lateral component.

4. In a pump having a rotatable cylinder barrel provided with substantially radial cylinders and a valve member through which liquid may flow to and from said cylinders and against which said cylinder barrel bears and is restrained thereby from movement in one axial direction, the combination of a piston fitted in each cylinder and provided upon its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge each piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution and thereby cause said pistons to pump liquid through said valve member, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of each piston upon a single spot offset from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in each piston a centrifugal force the lateral component of which tends to move said cylinder barrel axially in a direction to increase the bearing pressure between said cylinder barrel and said valve member, and means independent of said pumping pistons for generating a centrifugal force the lateral component of which counteracts the lateral component of the centrifugal force generated in said piston by rotation of said cylinder barrel.

5. A pump, comprising a rotatable cylinder bar-

rel having substantially radial cylinders arranged therein, a valve member through which liquid may flow to and from said cylinders and against which said cylinder barrel bears and is restrained thereby from movement in one axial direction, a piston fitted in each cylinder to reciprocate therein and provided upon its outer end with a contact face inclined to the piston axis, means for rotating said cylinder barrel, a thrust ring arranged around said cylinder barrel eccentric thereto to urge each piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of each piston upon one side of the piston axis to transmit pumping forces to that piston, the reaction of said pistons against said reaction surface during rotation of said cylinder barrel causing to be generated in said pistons centrifugal forces the lateral components of which tend to move said cylinder barrel axially in a direction to increase the bearing pressure between said cylinder barrel and said valve member, and means for counteracting the effect upon said cylinder barrel of said lateral components without altering the effect upon said cylinder barrel of the lateral components of said pumping forces.

6. A pump, comprising a rotatable cylinder barrel having substantially radial cylinders arranged therein, a valve member through which liquid may flow to and from said cylinders and against which said cylinder barrel bears and is restrained thereby from movement in one axial direction, a piston fitted in each cylinder to reciprocate and rotate therein and provided upon its outer end with an annular contact face inclined to the piston axis, means for rotating said cylinder barrel, a thrust ring arranged around said cylinder barrel eccentric thereto to urge each piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of each piston upon a single spot offset from the axis of that piston to transmit pumping forces to that piston and to rotate the same during reciprocation thereof, the reaction of said pistons against said reaction surface during rotation of said cylinder barrel causing to be generated in said pistons centrifugal forces the lateral components of which tend to move said cylinder barrel axially in a direction to increase the bearing pressure between said cylinder barrel and said valve member, and means for counteracting the effect upon said cylinder barrel of said lateral components without altering the effect upon said cylinder barrel of the lateral components of said pumping forces.

7. A pump, comprising a pintle tapering toward its front end, a cylinder barrel journaled upon said pintle to rotate thereon and provided with a substantially radial cylinder, a piston fitted in said cylinder and provided upon its outer end with a contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during another half revolution, a conical reaction surface arranged upon said thrust ring and tapered in the same direction as the pintle taper, said reaction surface engaging the contact face of said piston in front of the piston axis to transmit thrust to said piston whereby during rotation of said cylinder barrel the lateral component of the centrifugal force generated in said piston by rotation of said cylinder barrel tends to move said cylinder barrel toward the large end of said pintle, and means for generating another force to counteract the effect upon said cylinder barrel of said lateral component.

8. A pump, comprising a pintle tapering toward its front end, a cylinder barrel journaled upon said pintle to rotate thereon and provided with a substantially radial cylinder, a piston fitted in said cylinder and provided upon its outer end with a contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during another half revolution, a conical reaction surface arranged upon said thrust ring and tapered in the same direction as the pintle taper, said reaction surface engaging the contact face of said piston in front of the piston axis to transmit thrust to said piston whereby during rotation of said cylinder barrel the lateral component of the centrifugal force generated in said piston by rotation of said cylinder barrel tends to move said cylinder barrel toward the large end of said said pintle, and means for generating another centrifugal force the lateral component of which is substantially equal and opposite in direction to the lateral component of the centrifugal force generated in said piston.

9. A pump, comprising a pintle tapering toward its front end, a cylinder barrel journaled upon said pintle to rotate thereon and provided with a substantially radial cylinder, a piston fitted in said cylinder and provided at its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a reaction surface arranged upon said thrust ring at an angle to the axis thereof and engaging the contact face of said piston upon a single spot offset forward from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in said piston a centrifugal force the lateral component of which tends to move the cylinder barrel toward the large end of said pintle, and means for generating a counteracting force which tends to move said cylinder barrel toward the small end of said pintle.

10. In a pump provided with a rotatable cylinder barrel having a plurality of substantially radial cylinders, a valve member through which liquid may flow to and from said cylinders, a pumping piston fitted in each cylinder and provided at its outer end with a contact face inclined to the piston axis, and a substantially conical bearing surface engaging the contact faces on said pistons and arranged around said cylinder barrel eccentric thereto whereby rotation of said cylinder barrel causes said pistons to be urged against said bearing surface by centrifugal force and said bearing surface to transmit pumping forces to said pistons and the lateral components of said centrifugal and pumping forces to tend to move said cylinder barrel axially in a given direction, the combination of a substantially conical reaction surface arranged around said cyl-

inder barrel and inclined opposite to the inclination of said bearing surface, and non-pumping pistons arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel in the opposite direction.

11. In a pump having a rotatable cylinder barrel provided with a substantially radial cylinder, and a valve member through which liquid may flow to and from said cylinder, the combination of a pumping piston fitted in said cylinder and provided upon its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a substantially conical bearing surface arranged upon said thrust ring and engaging the contact face of said piston upon a single spot offset from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in said piston a centrifugal force the lateral component of which tends to move said cylinder barrel axially in one direction, a substantially conical reaction surface arranged around said cylinder barrel and inclined opposite to the inclination of said bearing surface, and a non-pumping piston arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel in the opposite direction and thereby counteract the effect upon said cylinder barrel of the centrifugal force generated in said pumping piston.

12. A pump comprising a pintle tapering toward its front end, a cylinder barrel journaled upon said pintle to rotate thereon and provided with a substantially radial cylinder, a pumping piston fitted in said cylinder and provided upon its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a substantially conical bearing surface arranged upon said thrust ring and tapered in the same direction as said pintle taper, said bearing surface engaging the contact face of said piston upon a single spot offset forward from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in said piston a centrifugal force the lateral component of which tends to move said cylinder barrel toward the large end of said pintle, a substantially conical reaction surface arranged around said cylinder barrel and inclined opposite to the inclination of said bearing surface, and a non-pumping piston arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel toward the small end of said pintle.

13. In a pump provided with a rotatable cylinder barrel having a plurality of substantially radial cylinders, a valve member through which liquid may flow to and from said cylinders, a pumping piston fitted in each cylinder and provided at its outer end with a contact face inclined to the piston axis, and a substantially conical bearing surface engaging the contact faces on said pistons and arranged around said cylinder barrel eccentric thereto whereby rotation of said cylinder barrel causes said pistons to be urged against said bearing surface by centrifugal force and said bearing surface to transmit pumping forces to said pistons and the lateral components of said centrifugal and pumping forces to tend to move said cylinder barrel axially in a given direction, the combination of a substantially conical reaction surface arranged around said cylinder barrel and inclined opposite to the inclination of said bearing surface, and non-pumping pistons arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel in the opposite direction; said non-pumping pistons being so arranged as to be lubricated by liquid moved by said pumping pistons.

14. A pump comprising a pintle tapering toward its front end, a cylinder barrel journaled upon said pintle to rotate thereon and provided with a substantially radial cylinder, a pumping piston fitted in said cylinder and provided upon its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a substantially conical bearing surface arranged upon said thrust ring and tapered in the same direction as said pintle taper, said bearing surface engaging the contact face of said piston upon a single spot offset forward from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in said piston a centrifugal force the lateral component of which tends to move said cylinder barrel toward the large end of said pintle, a substantially conical reaction surface arranged around said cylinder barrel and inclined opposite to the inclination of said bearing surface, and a non-pumping piston arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel toward the small end of said pintle; said non-pumping piston being so arranged as to be lubricated by liquid moved by said pumping piston.

15. In a pump provided with a rotatable cylinder barrel journaled upon a pintle, pumping pistons arranged substantially radially in said cylinder barrel and having inclined contact faces upon the outer ends thereof, and a substantially conical bearing surface engaging the beveled outer ends of said pistons and arranged around said cylinder barrel eccentric thereto whereby rotation of said cylinder barrel causes said pistons to be urged against said bearing surface by centrifugal force and said bearing surface to transmit pumping forces to said pistons and the lateral components of said centrifugal and pumping forces to tend to move said cylinder barrel axially in a given direction, the combination of a substantially conical reaction surface arranged around said cylinder barrel and inclined opposite to the inclination of said bearing surface, and non-pumping pistons arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel in the opposite direction; said non-pumping pistons be-

ing fitted in cylinders which are arranged in said cylinder barrel and open to liquid seeping between said cylinder barrel and said pintle whereby said seepage liquid lubricates said non-pumping pistons.

16. A pump comprising a pintle, a cylinder barrel journaled upon said pintle to rotate thereon and provided with a radial cylinder, a pumping piston fitted in said cylinder and provided upon its outer end with an annular contact face inclined to the piston axis, a thrust ring arranged around said cylinder barrel eccentric thereto to urge said piston inward during one half revolution of the cylinder barrel and to permit it to move outward during the other half revolution, a substantially conical bearing surface arranged upon said thrust ring and engaging the contact face of said piston upon a single spot offset from the piston axis to transmit thrust to said piston and to rotate the same during reciprocation thereof, rotation of said cylinder barrel causing to be generated in said piston a centrifugal force the lateral component of which tends to move said cylinder barrel axially in one direction, a substantially conical reaction surface arranged around said cylinder barrel and inclined opposite to the inclination of said bearing surface, and a non-pumping piston arranged in said cylinder barrel and urged against said reaction surface by centrifugal force the lateral component of which tends to move said cylinder barrel in the opposite direction; said non-pumping piston being fitted in a cylinder which is arranged in said cylinder barrel and open to liquid seeping between said cylinder barrel and said pintle whereby said seepage liquid lubricates said non-pumping piston.

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