Oct. 10, 1933. W. FERRIS 1,930,163

PUMP

Filed Jan. 12, 1931 4 Sheets-Sheet 1

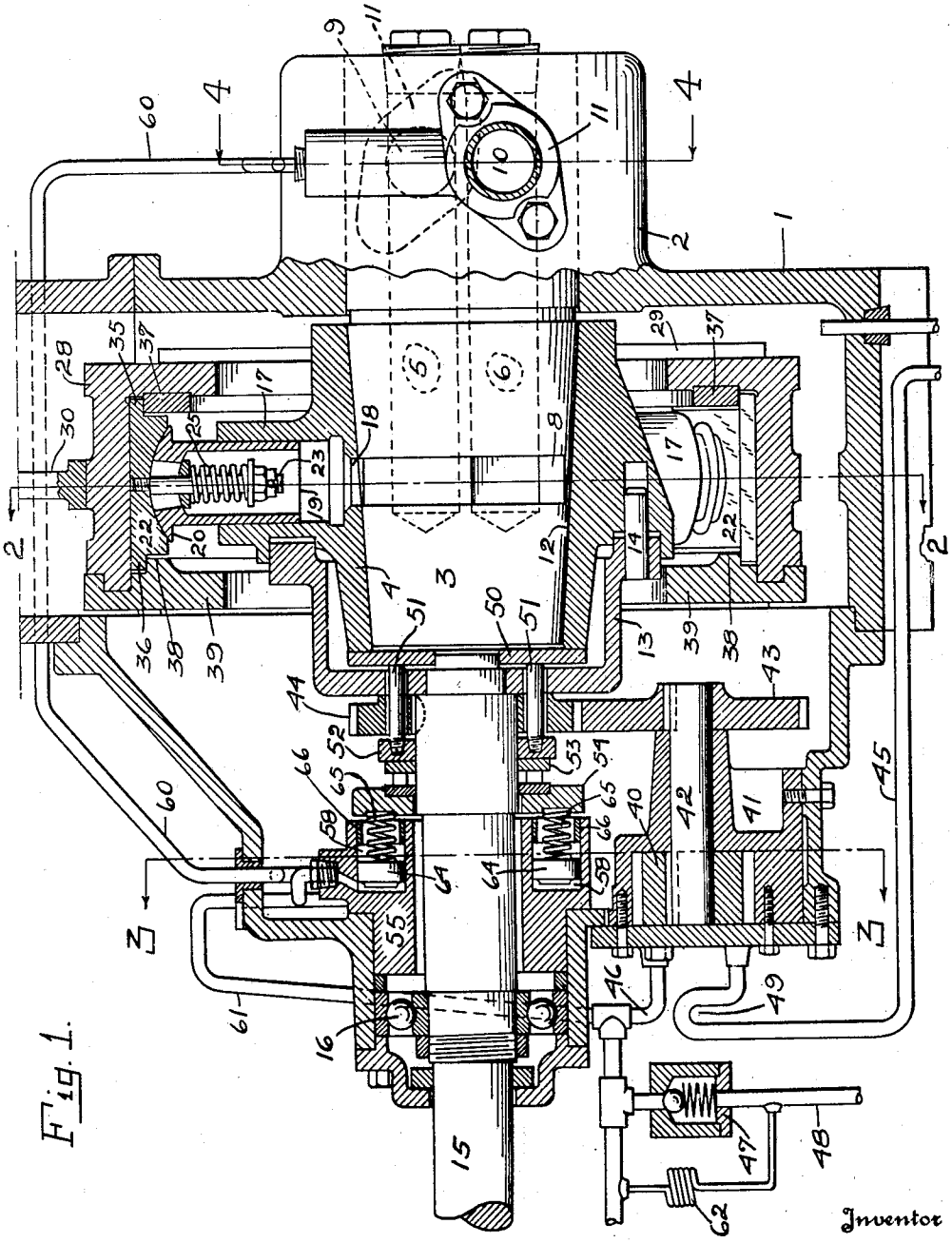


Fig. 1.

Inventor

WALTER FERRIS

By Wesley Merrill

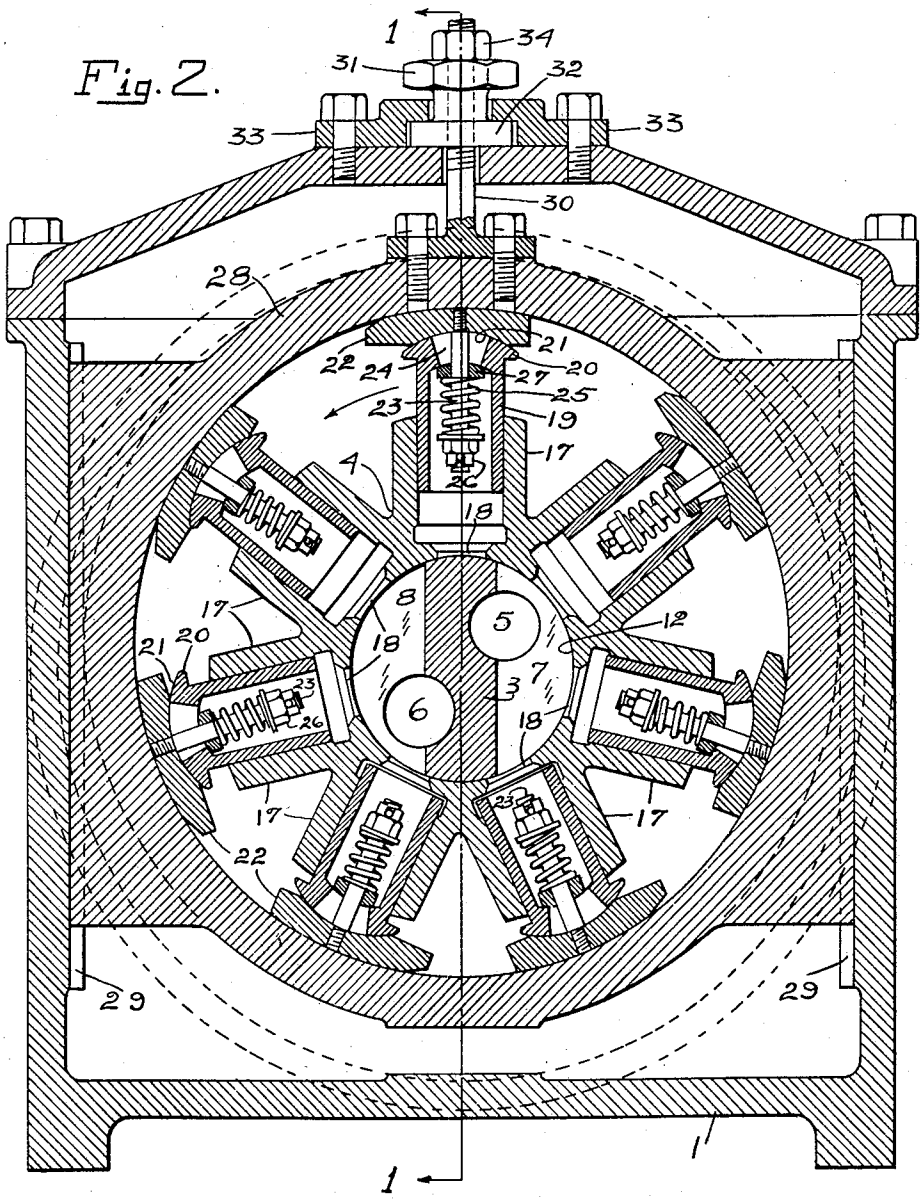
Attorney

Oct. 10, 1933. W. FERRIS 1,930,163

PUMP

Filed Jan. 12, 1931 4 Sheets-Sheet 2

Fig. 2.




Inventor

WALTER FERRIS.

By Wesley P. Merrill

Attorney

Oct. 10, 1933. W. FERRIS 1,930,163

PUMP

Filed Jan. 12, 1931 4 Sheets-Sheet 3

Fig. 3.

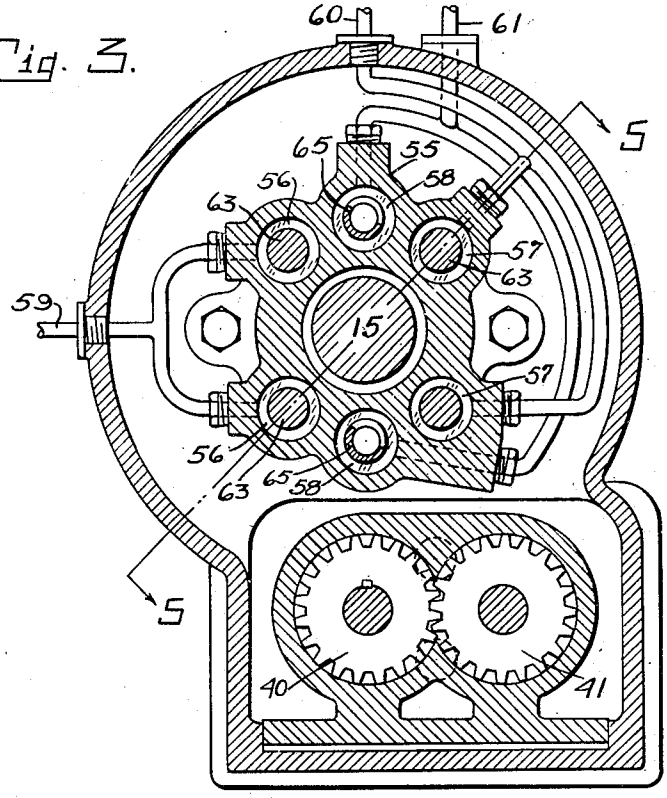
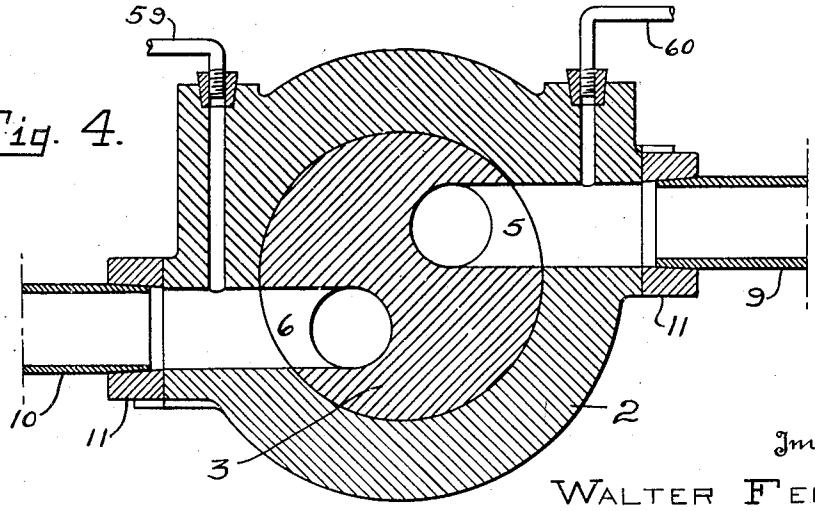



Fig. 4.




Inventor

WALTER FERRIS.

By Wesley P. Merrill

Attorney

Oct. 10, 1933. W. FERRIS 1,930,163

PUMP

Filed Jan. 12, 1931 4 Sheets-Sheet 4

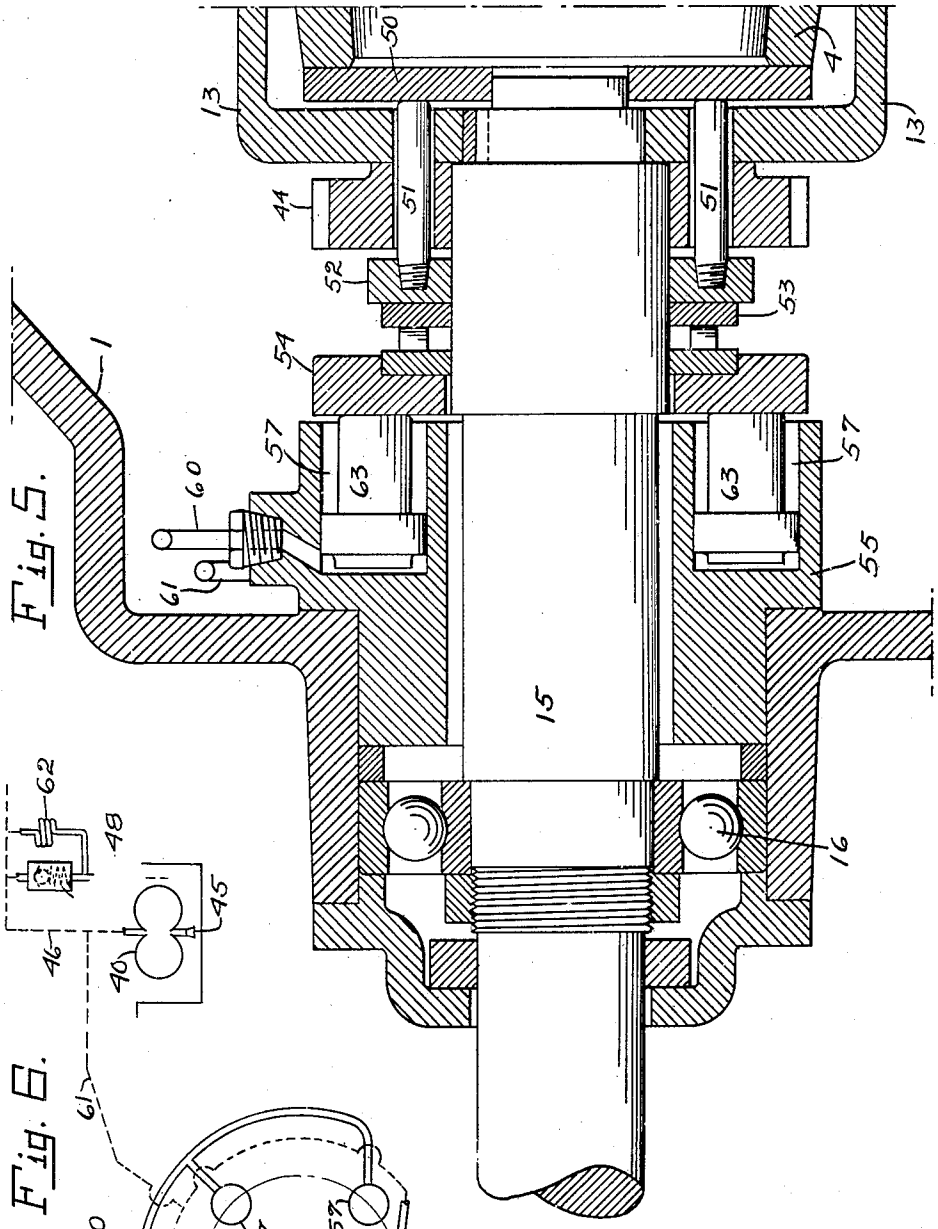



Fig. 5.

Fig. 6.

Inventor

WALTER FERRIS.

By Wesley P. Merrill

Attorney

Patented Oct. 10, 1933

1,930,163

# UNITED STATES PATENT OFFICE

1,930,163

## PUMP

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

Application January 12, 1931. Serial No. 508,103

16 Claims. (Cl. 103—161)

This invention relates to positive displacement pumps.

The pump to which the invention applies in particular has a cylinder barrel journaled upon a central shaft or pintle having intake and discharge ports and passageways formed therein, cylinders arranged radially in the cylinder barrel to communicate alternately with the intake and discharge ports as the cylinder barrel rotates, and pistons arranged in the cylinders and reciprocated therein by an actuator which is eccentric to the axis of the pintle and engages the ends of the pistons.

The coacting surfaces of the cylinder barrel and the pintle are separated by a film of the working fluid of the pump and this film is subjected at all times to pump pressure.

Such pumps are frequently employed to perform work which requires the highest possible degree of accuracy in the delivery rate of the pump during a wide variation in certain factors which tend to change the delivery rate, such as the variation in the viscosity of the working fluid due to temperature changes and variation in the pressure of the working fluid due to variation in the resistance encountered thereby.

The working fluid is ordinarily a good quality of lubricating oil which provides a satisfactory film between the coacting surfaces of the cylinder barrel and the pintle but which varies in viscosity in accordance with the variation of the temperature thereof.

The clearance between the coacting surfaces of the cylinder barrel and the pintle is ordinarily sufficient to allow a film of oil in its heaviest or most viscous state to be formed therein and, as this film is subjected at all times to pump pressure, a certain amount of oil leaks from between these surfaces and this leakage is generally designated as the slip of the pump.

At room temperatures and under low pressures, this slip is negligible relatively to the volumetric capacity of the pump but it increases in response to increases in pressure and temperature, an increase in temperature reducing the viscosity of the oil and allowing it to flow more freely from between the pintle and the cylinder barrel and an increase in pressure forcing the oil more rapidly from between the pintle and the cylinder barrel.

As an illustration, a certain size of a pump which is used extensively to operate machine tool feeds has a slip of about 20 cubic inches per minute at moderate temperatures and pressures, but temperatures and pressures are often created which cause the slip to increase to 30 cubic inches per minute.

A variation in slip of 10 cubic inches is negligible relative to the volumetric capacity of the pump but it often happens that a delivery of only 20 cubic inches is required to produce the desired feeding speed and then a variation of 10 cubic inches in slip will cause an error of 50% in the feeding speed.

The larger pumps of this character are often employed to deliver large volumes of liquid at high pressures and have a correspondingly large slip or leakage which results in a significant loss of power. Further, the energy of the escaping liquid reappears as heat which soon heats the entire liquid contents of the pump and its hydraulic circuit far beyond the efficient working temperature thereof.

In order to reduce slip and to maintain the net delivery of the pump as constant as possible, the clearance between the pintle and the cylinder barrel of the prior pump has been reduced far below that ordinarily allowed between relatively rotating parts of corresponding diameters, and devices responsive to an increase in pressure have been provided for increasing the stroke of the pump to compensate for the increase in slip caused by the increase in pressure.

It has been found, however, that it is necessary to compensate for variations in both pressure and temperature in order to maintain the net delivery of the pump constant, as compensating mechanism responsive solely to variations in pressure will produce widely varying results when the temperature of the oil varies through a wide range.

The present invention has as an object to provide a pump in which the net delivery remains substantially constant throughout a wide range of variation in temperature and pressure.

Another object is to keep the slip of the pump at a substantially constant minimum throughout a wide range of temperature and pressure variations.

Another object is to increase the pressure exerted by the cylinder barrel upon the lubricating film in proportion to the increase in pump pressure.

Another object is to compensate for wear upon the coacting surfaces of the pintle and the cylinder barrel.

According to the invention in one of its aspects, the pintle and the bore of the cylinder barrel are tapered, an axial force tends to urge the cylinder barrel and the pintle into contact with each other, and this axial force increases as the pressure created by the pump increases.

According to the invention in another aspect, the cylinder barrel and the pintle are urged toward each other when the pump is in operation by a force which remains substantially constant and by another force which varies in proportion to the variation in the pressure created by the pump.

The invention further provides a pump of this character in which the axial forces are entirely removed when the pump is idle in order to allow a film of lubricant to remain between the coacting surfaces of the pintle and the cylinder barrel.

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

Fig. 1 is a central longitudinal section through a pump in which the invention is embodied, the view being taken substantially on the line 1—1 of Fig. 2 and certain parts being shown in full.

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

Fig. 3 is a transverse section showing the thrust mechanism and the gear pump, the view being taken on a line 3—3 of Fig. 1.

Fig. 4 is a transverse section showing the intake and discharge passageways, the view being taken on a line 4—4 of Fig. 1.

Fig. 5 is a longitudinal section through the thrust mechanism, taken on a line 5—5 of Fig. 3.

Fig. 6 is a schematic drawing of the hydraulic circuit.

The pump has its mechanism arranged within a supporting casing 1 having a hub 2 upon the rear wall thereof to support a pintle 3 which has a cylinder barrel 4 journaled upon its inner end and its outer end fixed in the hub 2 and held against rotation therein.

The pintle 3 is provided with axial intake and discharge passageways 5 and 6 communicating, respectively, with two segmental ports 7 and 8 formed in the pintle and with two external pipes 9 and 10 each of which is attached to the hub 2 by means of a pipe flange 11.

Either of the passageways may function as an intake and the other passageway as an outlet but, for the purpose of illustration, it is assumed that the cylinder barrel is to be rotated in the direction of the arrow in Fig. 2 and that the pipe 9, the passageway 5 and the port 7 ordinarily constitute the intake of the pump and port 8, passageway 6 and pipe 10 the outlet thereof.

The bore 12 of the cylinder barrel 4 and that part of the pintle 3 enclosed thereby are tapered and the clearance between the coacting surfaces thereof is regulated by adjusting the cylinder barrel axially upon the pintle.

If this taper is slight, a small force upon the front end of the cylinder barrel will cause it to wedge upon the pintle and, if the taper is too steep, a great force is required to hold the cylinder barrel in axial adjustment.

The taper, therefore, should be steep enough to prevent the cylinder barrel from sticking upon the pintle, even when a large force is applied to its front end, but not steep enough to require excessively powerful mechanism to hold the cylinder barrel against the axial component of the force exerted upon the inner surface of the cylinder bore by the high pressure which the pump is capable of developing. In practice, it is found that a taper of approximately 1¾ inches in diameter per foot is satisfactory.

The cylinder barrel 4 is provided with an annular groove concentric with the pintle 3 to receive the inner annular edge of a circular flanged driver 13 which is connected to the cylinder barrel 4, by driving pins 14 and has its outer end rigidly secured to a driving shaft 15 journaled in a bearing 16 carried by the front wall of the casing 1.

The shaft 15 is driven from an external source of power and it drives the cylinder barrel 4 through the driver 13 and the pins 14, the circular flange of the driver 13 and the pins 14, allowing the cylinder barrel to move slightly relatively to the driver 13 in response to variations in pressure created by the pump.

The cylinder barrel 4 is provided with a number of radial cylinders 17 each of which has a port 18 communicating with the bore 12 in alinement with the ports 7 and 8 to register alternately therewith as the cylinder barrel rotates.

Each of the cylinders 17 has a hollow piston 19 fitted therein and provided at its outer end with a head 20 which has spherical outer and inner faces and engages a complementary concave seat 21 formed in the inner surface of a crosshead 22.

Each piston 19 and its associated crosshead 22 are connected to each other by a spring bolt 23 which extends through a central aperture 24 in the head 20 and has its outer end threaded into the crosshead 22 and its inner part encircled by a helical compression spring 25 arranged between an adjusting nut 26 and a thrust washer 27 having a convex outer surface in engagement with the complementary concave inner surface of the head 20.

The outer faces of the crossheads 22 are complementary to and engage the cylindrical inner surface of a non-rotatable cam ring 28 which is adjustable vertically to vary the stroke of the pump and held against axial displacement by two guides 29 carried by the sides of the casing 1.

The cam ring 28 has an adjusting bolt 30 secured to its upper edge and threaded through an adjusting nut 31 supported by the top of the casing 1. The nut 31 is held against axial movement by an annular flange 32 formed thereon and arranged between the top of the casing 1 and two lugs 33 which are removably secured to the casing 1 and overlap the upper side of the flange 32, and the adjusting nut 31 may be secured in adjusted positions by a lock nut 34 threaded upon the outer end of the bolt 30.

The adjusting bolt 30 is employed to raise and lower the cam ring 28 to adjust its axis relatively to the axis of the pintle 3 and thereby adjust the stroke of the pump.

If the cam ring 28 is raised to its uppermost position and the cylinder barrel 4 rotates in the direction of the arrow on Fig. 2, the pump will deliver liquid at its full volumetric capacity through the port 8 and the passageway 6. As the cam ring is lowered, the stroke and volumetric delivery of the pump decreases until the cam ring is concentric with the pintle 3 and then the stroke and the delivery of the pump is at zero. Further downward movement causes the pump to start delivering liquid through the port 7 and the passageway 5 and the stroke and delivery increases as the cam ring moves downward until it reaches its lowermost position at which time the pump is at full stroke and delivering liquid at its full volumetric capacity through the port 7 and the passageway 5.

Each crosshead 22 has a flange 35 formed along its rear edge and a flange 36 formed along its front edge and engaged, respectively, by a retaining ring 37 and an annular shoulder 38 which

are concentric to the inner periphery of the cam ring 28 and hold the crossheads against radially inward movement.

The retaining ring 37 is secured to the rear wall of the cam ring 28 and the annular shoulder 38 is formed upon a retaining ring 39 which is attached to the cam ring 28 and closes the front thereof.

If the cylinder barrel is rotated in the direction of the arrow shown in Fig. 2 and the cam ring is positioned with its axis above the axis of the pintle, the pistons at the right of the line 1—1 of Fig. 2 are drawn outward and their cylinders are filled with liquid drawn from a reservoir or other source (not shown) through the pipe 9, the passageway 5 and the port 7, and the pistons at the left of the line 1—1 are forced inward and liquid is expelled from their cylinders and discharged through the port 8, the passageway 6 and the pipe 10.

In order to provide an independent source of pressure liquid for control purposes and the like, the pump is provided with a conventional gear pump 40 which has its housing 41 carried by the front wall of the casing 1 and its driving shaft 42 provided with a gear 43 which meshes with a gear 44 secured upon the pump shaft 15.

The gear pump 40 draws liquid from the reservoir through a suction pipe 45 and delivers it into a low pressure supply pipe 46 having connected between itself and the reservoir a relief valve 47 through which excess liquid delivered by the gear pump is exhausted, the liquid exhausted through the relief valve 47 being preferably returned to the reservoir through a separate drain pipe 48 instead of through the suction pipe 45 as the exhausted oil is heated by being forced through the relief valve.

The suction pipe 45 is preferably carried above the intake of the gear pump, as by forming a loop or trap 49 therein, in order that the gear pump may retain a charge of liquid when the pump is idle and thereby avoid the necessity of priming it.

When the pump is idle, the cylinder barrel 4 rests loosely upon the pintle 3 in order to retain a film of oil between the coacting surfaces thereof but is held against a material amount of axial movement by a thrust ring 50 which engages its outer end and is carried by the inner end of the driving shaft 15.

The thrust ring 50 is abutted upon its front face by a number of thrust pins 51 which extend loosely through the driver 13 and the gear 44 and have their front ends secured to a thrust collar 52 arranged upon the shaft 15 and rotatable therewith.

The thrust collar 52 is separated by an anti-friction thrust bearing 53 from the head 54 of a thrust mechanism which surrounds the shaft 15 and has its frame 55 carried in a stationary position by the front wall of the casing 1.

The frame 55 has two variable-pressure cylinders 56 formed in one side thereof, two variable-pressure cylinders 57 formed in the other side thereof, and two constant-pressure cylinders 58 arranged diametrically opposite each other and between the cylinders 56 and 57.

The number and arrangement of cylinders may be varied to suit the requirements of any particular pump but the arrangement shown is preferable when the pump is to be reversed in service, the cylinders 56 functioning as high pressure cylinders when the pump is delivering liquid through the pipe 10 and the cylinders 57 functioning as high pressure cylinders when the pump is delivering liquid through the pipe 9.

The cylinders 56 are connected to the pipe 10 by a pipe 59, the cylinders 57 are connected to the pipe 9 by a pipe 60, and the cylinders 58 are connected to the low pressure supply pipe 46 by a pipe 61, as shown diagrammatically in Fig. 6, and the low pressure pipe 46 is connected to the drain pipe 48 through a choke 62 which allows liquid to drain from the cylinders 58 after the pump comes to rest.

Each of the cylinders 56 and 57 has a plunger 63 fitted therein to engage the head 54, and each of the cylinders 58 has a piston 64 fitted therein, a helical compression spring 65 arranged between the piston 64 and the head 54, and an annular stop 66 to limit the forward movement of the piston 64.

The pistons 64 and the springs 65 are employed to provide a predetermined constant end thrust upon the cylinder barrel 4, and the plungers 63 are employed to provide a variable end thrust thereon which is proportional to the pressure created by the pump.

Assuming that the pump is at rest after having been in operation, the oil has drained from the cylinders 58 through the choke 62 in response to the pressure exerted by the springs 65 so that the cylinder barrel is free from end thrust and is resting upon a film of oil which was maintained upon the pintle 3 during the previous operation, and the cylinders upon the suction side of the pump contain a quantity of oil.

When the pump is started, the cylinders containing oil will make at least one revolution and replenish the lubricating film on the pintle before the cylinder barrel is subjected to any end thrust.

However, the gear pump starts immediately to deliver liquid to the cylinders 58 and creates a pressure therein which is sufficient to advance the pistons 64 against the stops 66 and compress the springs 65 which exert a constant predetermined force upon the head 54 and through it and the bearing 53, thrust collar 52, pins 51 and thrust ring 50 upon the cylinder barrel 4.

This force urges the cylinder barrel rearward upon the pintle 3 and tends to reduce the clearance between the coacting surfaces thereof to prevent the slip of the pump from becoming excessive.

As soon as the liquid delivered by the variable delivery pump encounters a resistance, the pressure in the discharge pipe 10 rises and liquid under pressure flows through the pipe 59 into the cylinders 56 and urges the plungers 63 therein against the head 54 with a force proportional to the pressure created by the pump, thereby urging the cylinder barrel rearward and further reducing the clearance between it and the pintle.

When the pump is in operation, the cylinder barrel is thus urged rearward and the clearance between it and the pintle reduced by an axial force which is the resultant of a constant force, as determined by the tension of the springs 65, and a variable force which is proportional to the pressure created by the pump.

This axial force urges the bearing surface of the pintle toward the bearing surface of the cylinder barrel and compresses the film of oil therebetween until the resistance of this film equals the pressure applied thereon by the axial force.

When the oil becomes heated, it will flow more readily from between the cylinder barrel and pintle but its resistance against molecular displacement is also reduced so that the axial force

applied to the cylinder barrel is able to reduce the clearance between the cylinder barrel and pintle an amount corresponding to the change in the viscosity of the oil. Consequently, an axial force applied to the cylinder barrel will maintain the slip of the pump substantially constant at any given pressure throughout the entire range of temperatures to which the oil in the pump is subjected.

The axial force exerted by the springs 65 is sufficient to maintain the slip of the pump at a constant minimum until a predetermined pressure has been created by the pump, for instance 200#, and then the force exterted by the plungers 63 on the pressure side of the pump exceeds the force exerted by the springs 65 and it increases in accordance with the increase in pump pressure.

The slip of the pump is thus maintained at a substantially constant minimum through the entire range of its operating pressures and temperatures.

If the pump is reversed, the slip is controlled in exactly the same manner except that pressure liquid flows from the pipe 9, which is then the discharge pipe, through the pipe 60 to the cylinders 57 to force the plungers 63 therein against the head 54.

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

This invention is hereby claimed as follows:

1. A positive displacement pump, comprising a tapered pintle fixed in a stationary position and having intake and discharge ports, cylinders arranged around said pintle and having ports for communicating with the ports in said pintle, means for revolving said cylinders around said pintle, means for creating a substantially constant pressure between the coacting surfaces of said pintle and said cylinders, and hydraulic means for increasing said pressure in proportion to increases in pump pressure.

2. A positive displacement pump, comprising a tapered pintle having intake and discharge ports, cylinders arranged around said pintle and having ports for communicating with the ports in said pintle, means for providing relative rotation between said pintle and said cylinders, means for creating a substantially constant pressure between the coacting surfaces of said pintle and said cylinders when said pump is in operation, means for increasing said pressure in proportion to increases in pump pressure, and means for automatically relieving said constant pressure when said pump is idle.

3. In a positive displacement pump, the combination of a stationary tapered pintle, cylinders carried by said pintle and rotatable about the same, hydraulic means for exerting upon said cylinders a constant predetermined axial force for urging the same along said pintle toward the large end thereof and tending to reduce the clearance between the coacting surfaces of said pintle and said cylinders to thereby maintain the slip of said pump at a substantially constant minimum at low pressures, and other hydraulic means for exerting upon said cylinders a variable axial force proportional to pump pressure to maintain said minimum slip substantially constant throughout the operating range of said pump.

4. In a positive displacement pump, the combination of a tapered pintle, cylinders carried by said pintle and rotatable about the same, means for exerting upon said cylinders when said pump is in operation a constant predetermined axial force for urging the same along said pintle toward the large end thereof and tending to reduce the clearance between the coacting surfaces of said pintle and said cylinders to thereby maintain the slip of said pump at a substantially constant minimum at low pressures, other means for exerting upon said cylinders a variable axial force proportional to pump pressure to maintain said minimum slip substantially constant throughout the operating range of said pump, and means for automatically eliminating said constant axial force when said pump is idle.

5. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged around said bore and provided with ports communicating therewith, a tapered pintle fixed in a stationary position and fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for rotating said cylinder barrel, and hydraulic means responsive to pump pressure for applying an axial force to said cylinder barrel upon the discharge side only of said pump to create relative axial movement between said cylinder barrel and said pintle to thereby decrease the clearance between the coacting surfaces thereof.

6. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged radially around said bore and provided with ports communicating therewith, a tapered pintle fixed in a stationary position and fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for rotating said cylinder barrel, and hydraulic means responsive to pump pressure for applying an axial force to said cylinder barrel upon the discharge side only of said pump to create relative axial movement between said cylinder barrel and said pintle to thereby decrease the clearance between the coacting surfaces thereof.

7. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged around said bore and provided with ports communicating therewith, a tapered pintle fixed in a stationary position and fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for rotating said cylinder barrel, and means for moving said cylinder barrel axially of said pintle to thereby decrease the clearance between the coacting surfaces thereof in response to a substantially constant axial force and to a variable force proportional to pump pressure.

8. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged around said bore and provided with ports communicating therewith, a tapered pintle fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for providing relative rotation between said cylinder barrel and said pintle, means for producing when said pump is in operation relative axial movement between said cylinder barrel and said pintle to thereby decrease the clearance between the coacting surfaces thereof in response to a substantially constant axial force and to a variable force proportional to pump pressure, and means for automatically eliminating said constant force when said pump is idle.

9. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylin-

ders arranged around said bore and provided with ports communicating therewith, a tapered pintle fixed in a stationary position and fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for rotating said cylinder barrel upon said pintle, constant pressure means tending to urge said cylinder barrel along said pintle to thereby reduce the clearance between the coacting surfaces thereof, and means responsive to pump pressure for applying an axial force to said cylinder barrel upon the discharge side only of said pump in either direction of flow to assist said constant pressure means and thereby vary the clearance between the coacting surfaces of said cylinder barrel and said pintle in response to variations in pump pressure.

10. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged radially around said bore and provided with ports communicating therewith, a tapered pintle fixed in a stationary position and fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for rotating said cylinder barrel upon said pintle, hydraulic means for exerting a constant axial force upon said cylinder barrel to urge it toward the large end of said pintle and thereby reduce the clearance between the coacting surfaces thereof, and means responsive to pump pressure for applying an axial force to said cylinder barrel upon the discharge side only of said pump in either direction of flow to assist said constant force and thereby vary the clearance between the coacting surfaces of said cylinder barrel and said pintle in response to variations in pump pressure.

11. A positive displacement pump, comprising a tapered pintle having intake and discharge ports and passageways, a cylinder barrel fitted upon said pintle and having cylinders arranged therein and provided with ports for communicating with said pintle ports, a shaft for rotating said cylinder barrel upon said pintle, an auxiliary pump driven by said shaft, thrust members carried by said shaft and rotatable therewith for urging said cylinder barrel toward the large end of said pintle, a thrust member arranged upon said shaft is a stationary position, an anti-friction bearing arranged between said stationary member and said rotatable members, a cylinder block arranged around said shaft in a stationary position and provided with thrust cylinders, pistons arranged in certain of said thrust cylinders, springs arranged between said pistons and said stationary thrust member, stops for limiting the outward movement of said pistons, means connecting the cylinders containing said pistons to said auxiliary pump, plungers arranged in the other of said thrust cylinders and adapted to engage said stationary thrust member, and means connecting the cylinders containing said plungers to the passageways in said pintle.

12. A positive displacement pump, comprising a tapered pintle having intake and discharge ports and passageways, a cylinder barrel fitted upon said pintle and having cylinders arranged radially therein and provided with ports for communicating with said pintle ports, a shaft for rotating said cylinder barrel upon said pintle, an auxiliary pump driven by said shaft, thrust members carried by said shaft and rotatable therewith for urging said cylinder barrel toward the large end of said pintle, a thrust member arranged upon said shaft in a stationary position, an anti-friction bearing arranged between said stationary member and said rotatable members, a cylinder block arranged around said shaft in a stationary position and provided with thrust cylinders, pistons arranged in certain of said thrust cylinders, springs arranged between said pistons and said stationary thrust member, stops for limiting the outward movement of said pistons, means connecting the cylinders containing said pistons to said auxiliary pump, plungers arranged in the other of said thrust cylinders and adapted to engage said stationary thrust member, means connecting the plunger containing cylinders in each side of said cylinder block to the passageway in the same side of said pintle, and means for relieving the pressure in said piston containing cylinders after said pump stops.

13. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged around said bore and provided with ports communicating therewith, a tapered pintle fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for providing relative rotation between said cylinder barrel and said pintle, hydraulically operated means for exerting a constant axial force upon said cylinder barrel to urge it toward the large end of said pintle to reduce the clearance between said cylinder barrel and said pintle, means included in said hydraulically operated means for limiting the force exerted thereby upon said cylinder barrel, and other means independent of said hydraulically operated means and responsive to pump pressure for applying an axial force to said cylinder barrel independently of said constant force.

14. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged around said bore and provided with ports communicating therewith, a tapered pintle fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for providing relative rotation between said cylinder barrel and said pintle, hydraulically operated means for exerting a constant axial force upon said cylinder barrel to urge it toward the large end of said pintle to reduce the clearance between said cylinder barrel and said pintle, means included in said hydraulically operated means for limiting the force exerted thereby upon said cylinder barrel, other means independent of said hydraulically operated means and responsive to pump pressure for applying an axial force to said cylinder barrel independently of said constant force, and means for automatically eliminating said constant force when said pump is idle.

15. A positive displacement pump, comprising a cylinder barrel having a tapered bore and cylinders arranged around said bore and provided with ports communicating therewith, a tapered pintle fitted in said bore and having intake and discharge ports for communicating with said cylinder ports, means for providing relative rotation between said cylinder barrel and said pintle, hydraulically operated means for exerting a constant axial force upon said cylinder barrel to urge it toward the large end of said pintle to reduce the clearance between said cylinder barrel and said pintle, means included in said hydraulically operated means for limiting the force exerted thereby upon said cylinder barrel, and other means independent of said hydraulically operated means and responsive to pump pressure for ap-

plying an axial force to said cylinder barrel upon the pressure side only of said pump in either direction of delivery of liquid from said pump.

16. A positive displacement pump, comprising a tapered pintle having intake and discharge ports and passageways, a cylinder barrel fitted upon said pintle and having cylinders arranged therein and provided with ports for communicating with said pintle ports, a shaft for rotating said cylinder barrel upon said pintle, a driver connecting said shaft to said cylinder barrel and forming a universal joint between the same to allow said cylinder barrel to float freely upon said pintle, means for applying an axial force to said cylinder barrel to move the same along said tapered pintle to thereby reduce the clearance between the coacting surfaces thereof, and means for transmitting said axial force from said applying means to said cylinder barrel independently of said driver and said pintle.

WALTER FERRIS.