May 9, 1944. W. R. TUCKER 2,348,428

VARIABLE DELIVERY VANE PUMP

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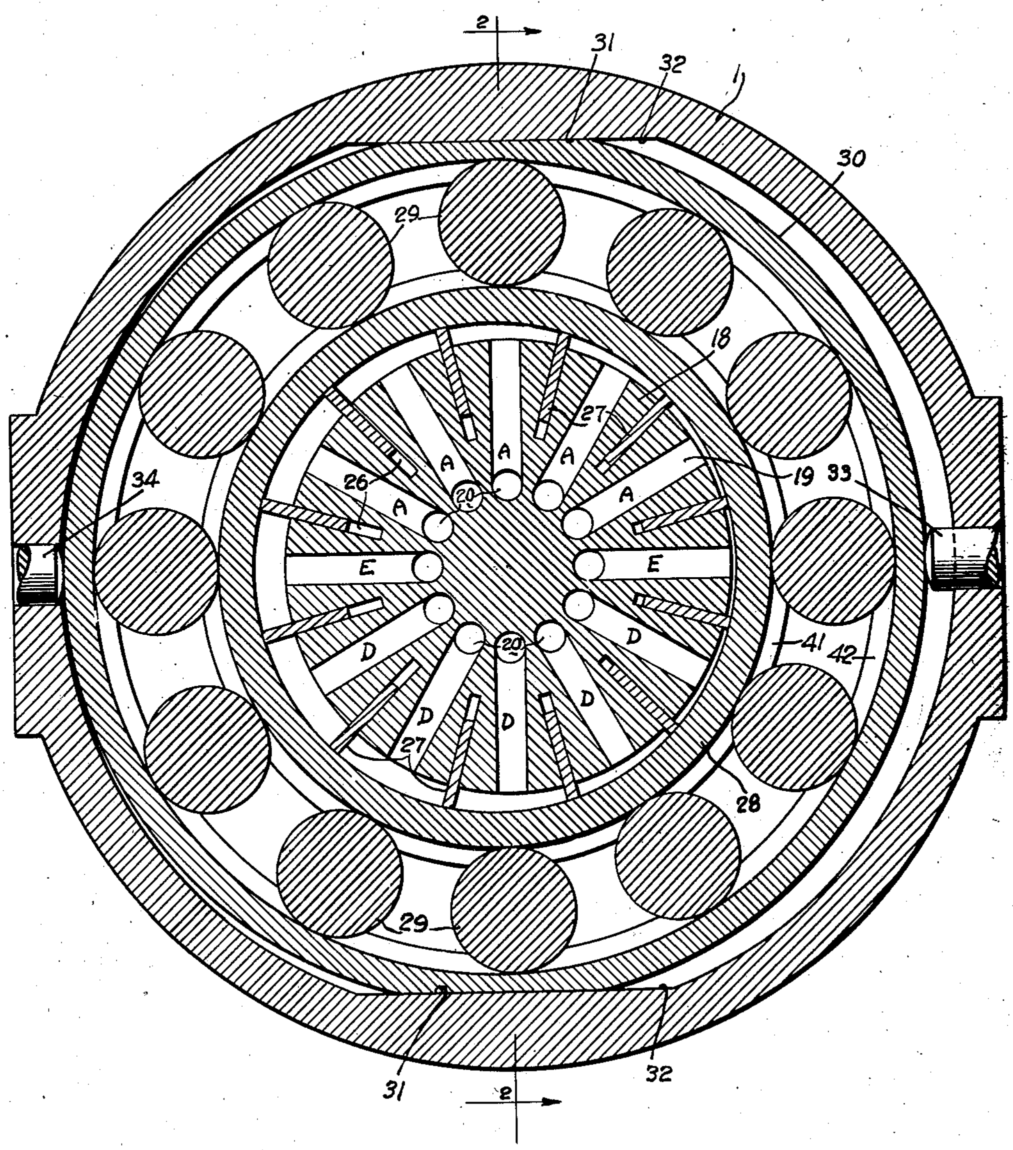
FIG. 1.



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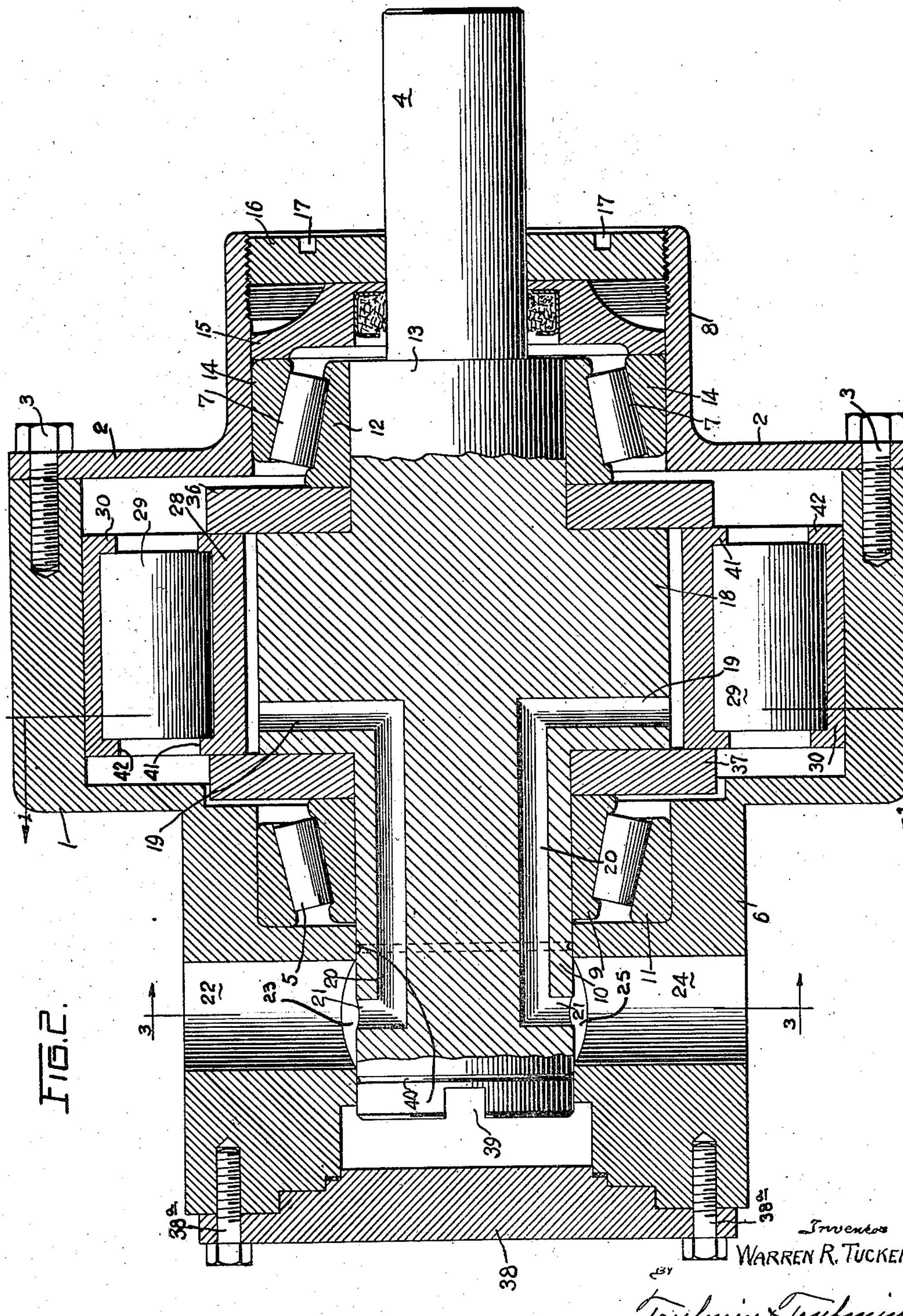

FIG. 2.

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FIG. 3.

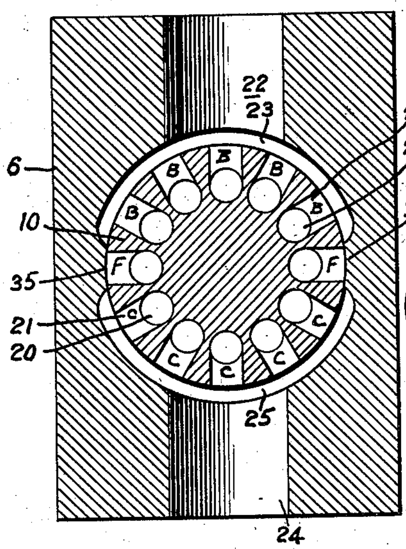


FIG. 5.

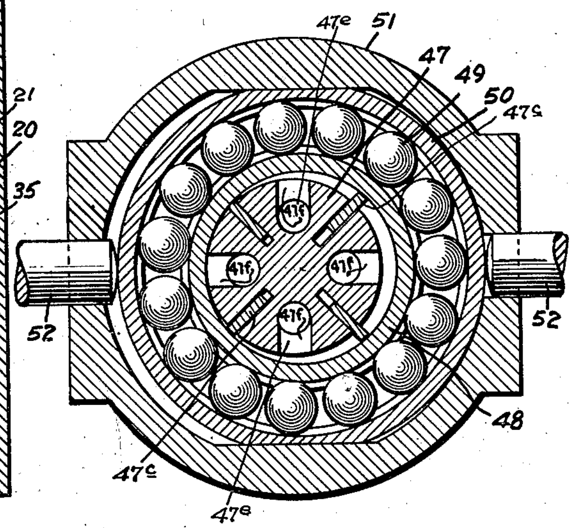
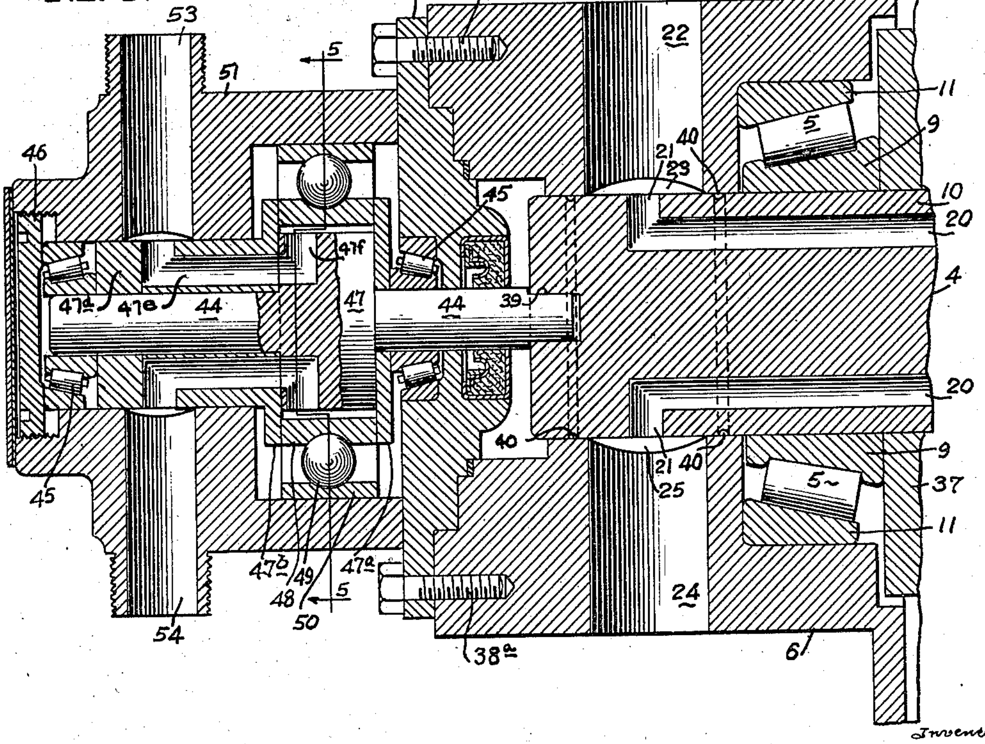


FIG. 4.



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VARIABLE DELIVERY VANE PUMP

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FIG. 6

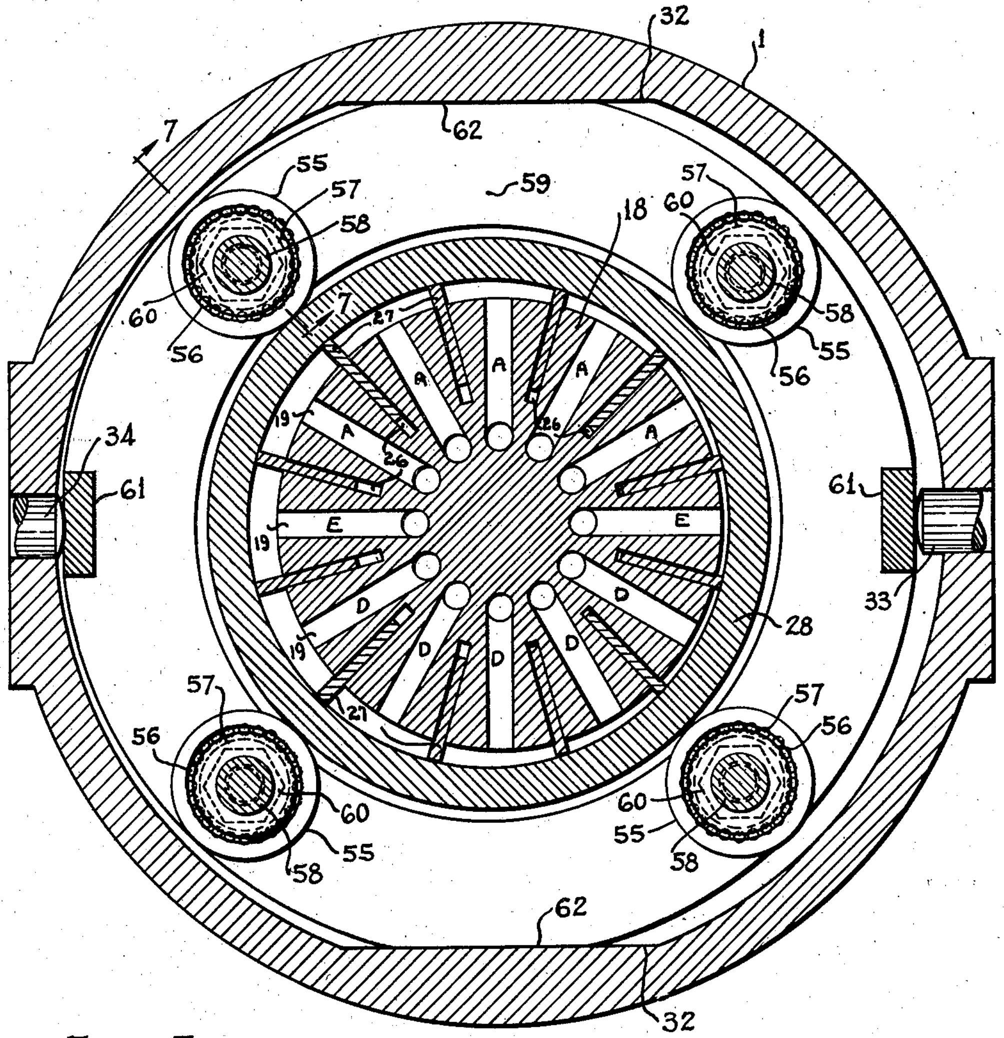
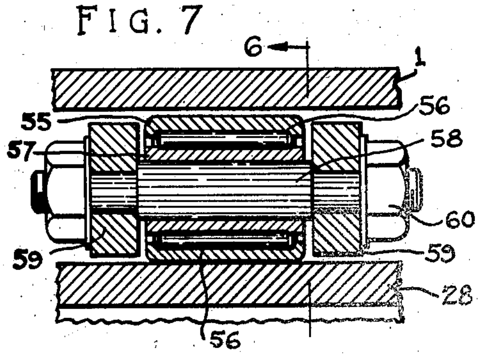


FIG. 7



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VARIABLE DELIVERY VANE PUMP

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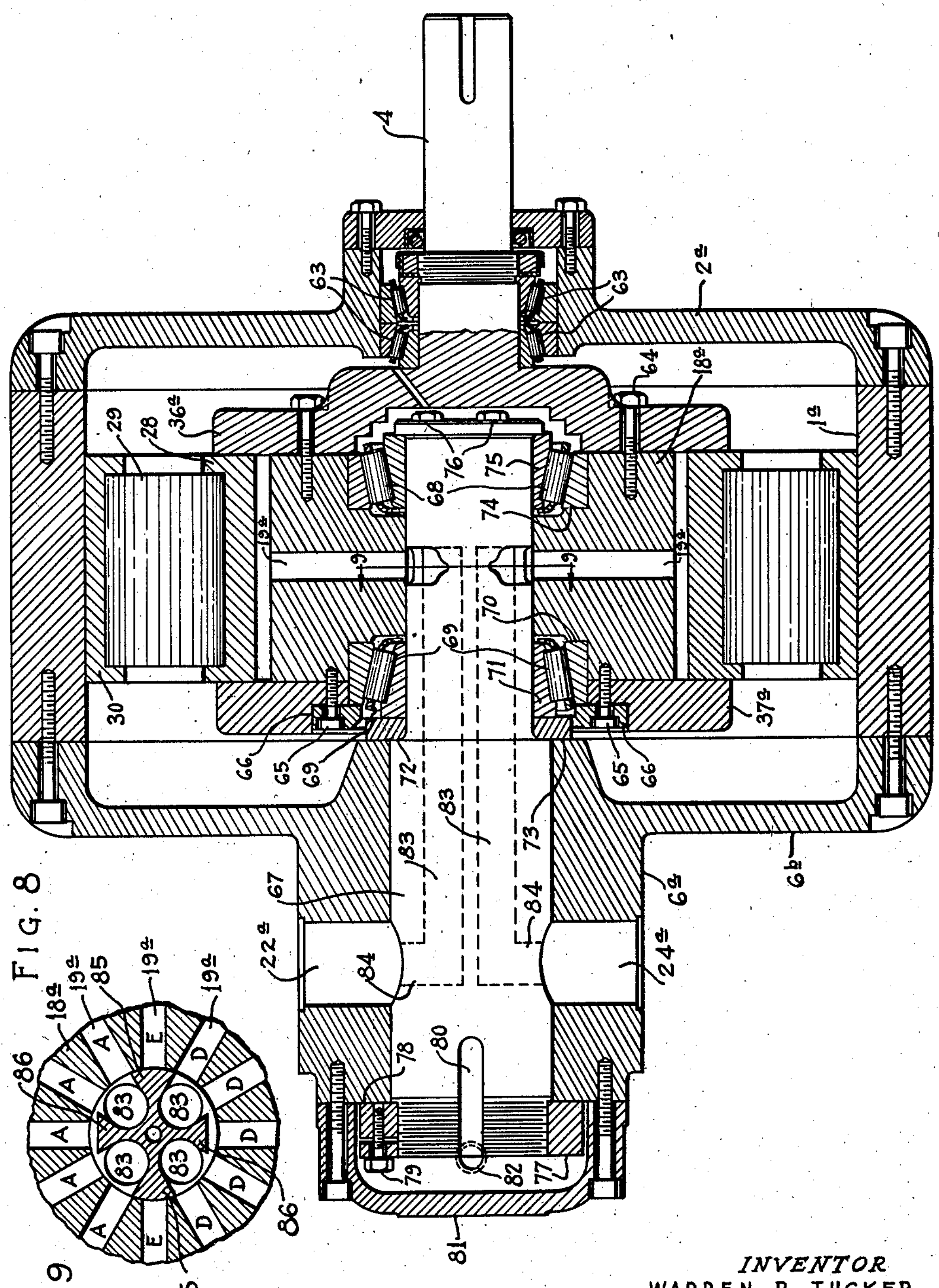

FIG. 8

FIG. 9

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VARIABLE DELIVERY VANE PUMP

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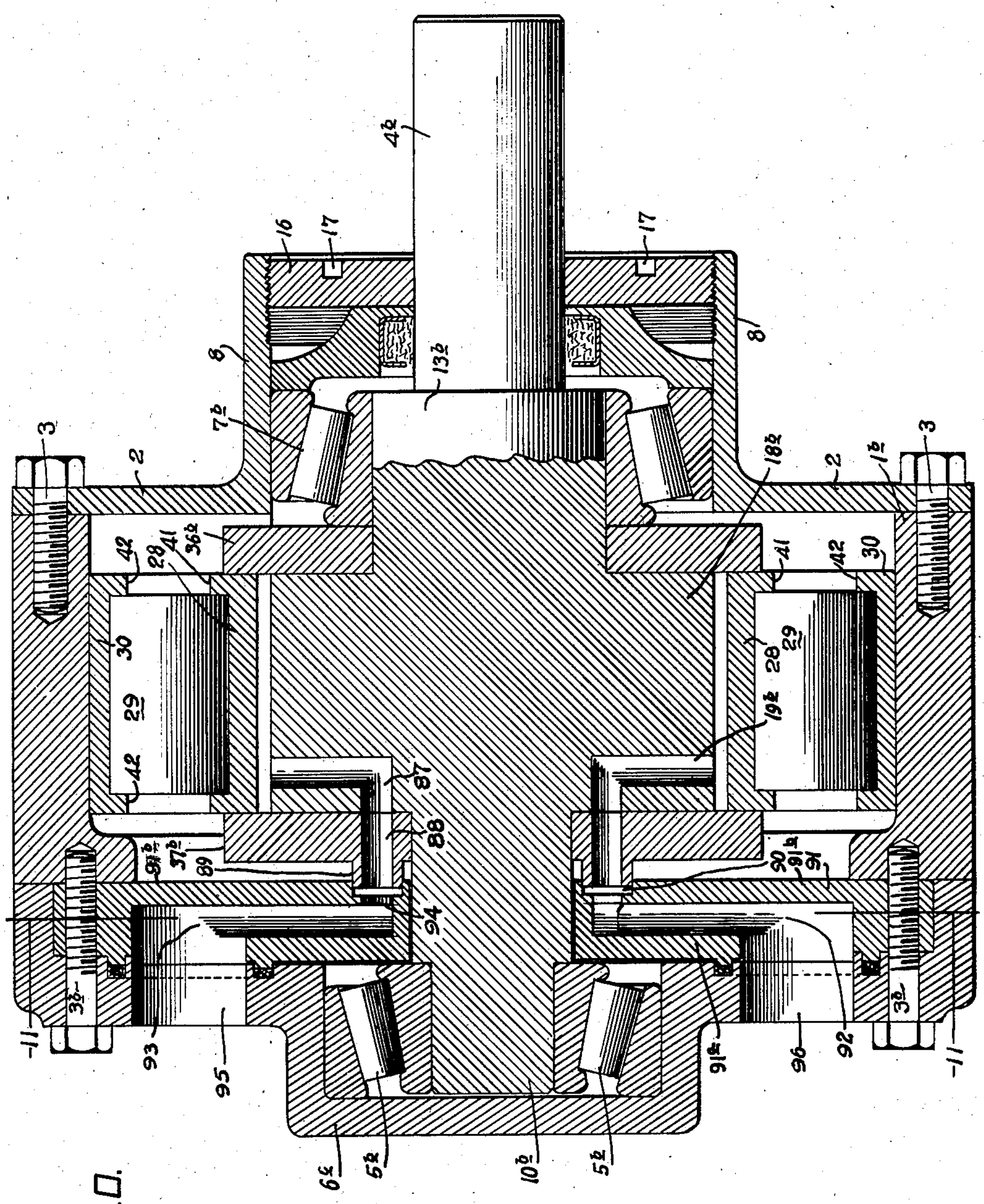

FIG. 10.

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FIG. 11.

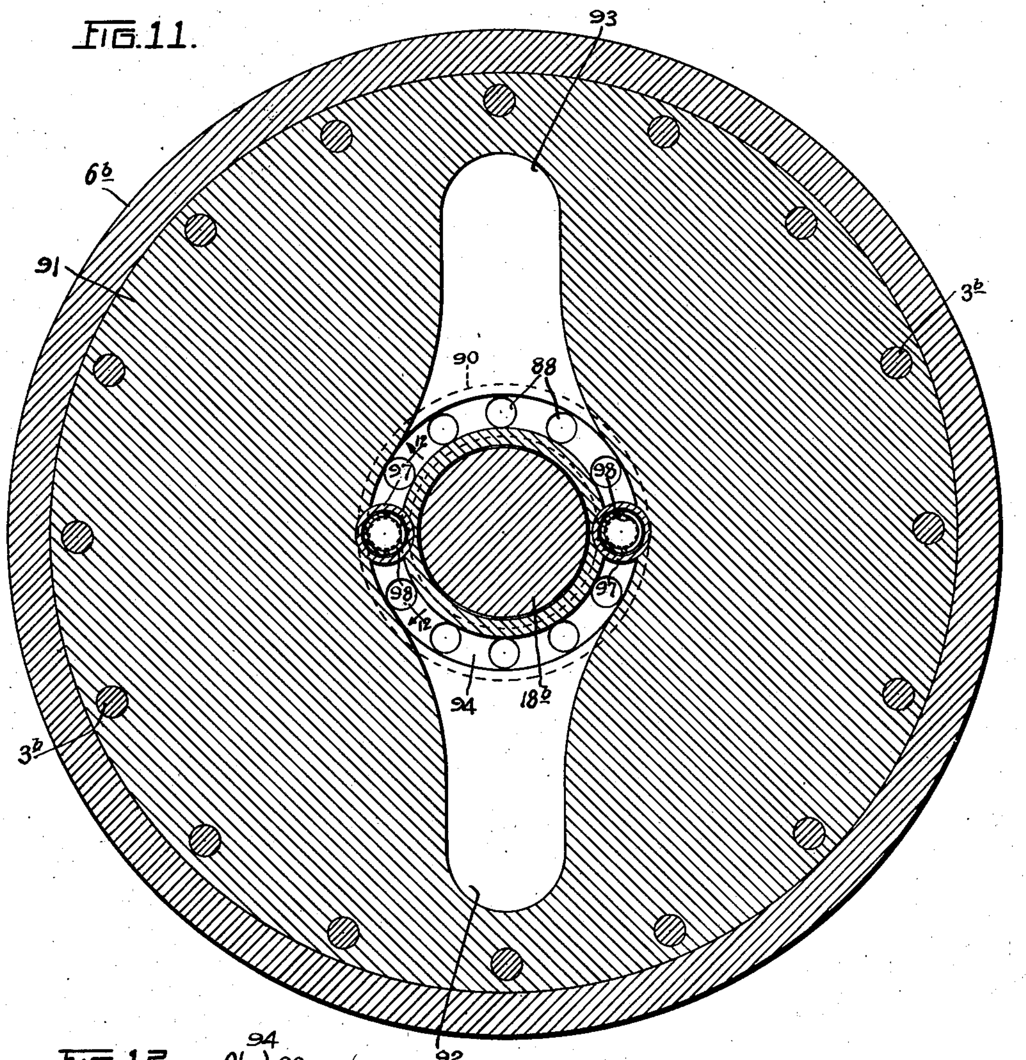

FIG. 12.

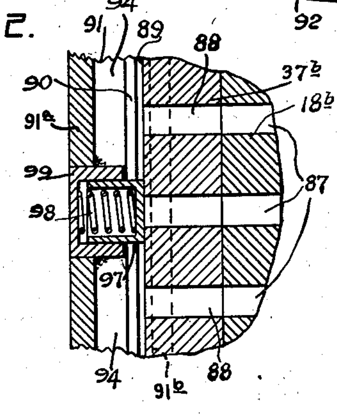

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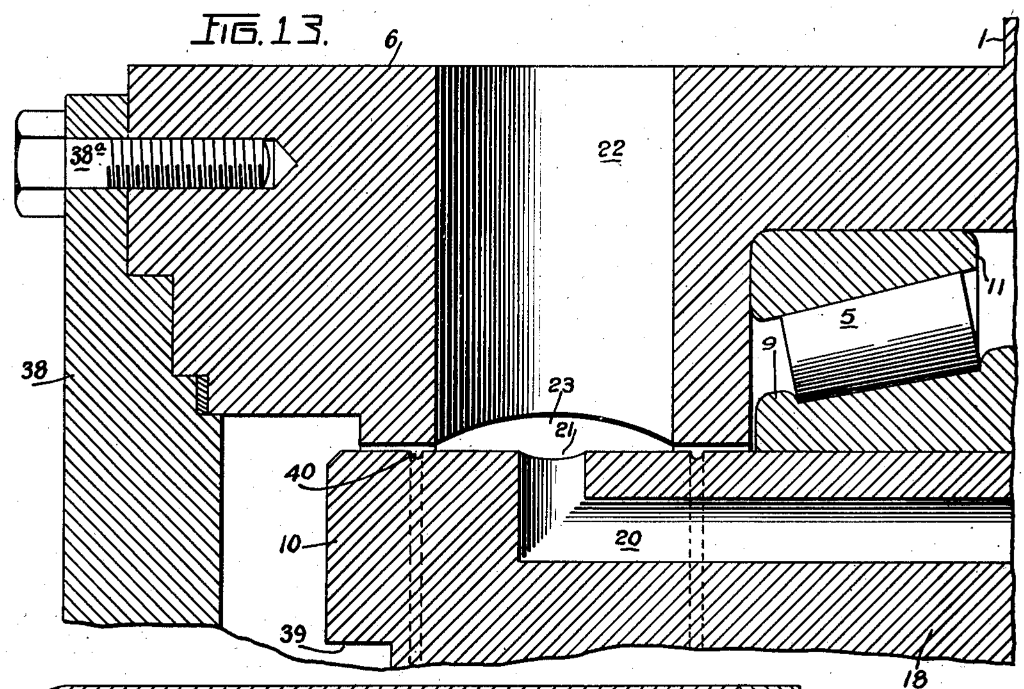
FIG. 13.



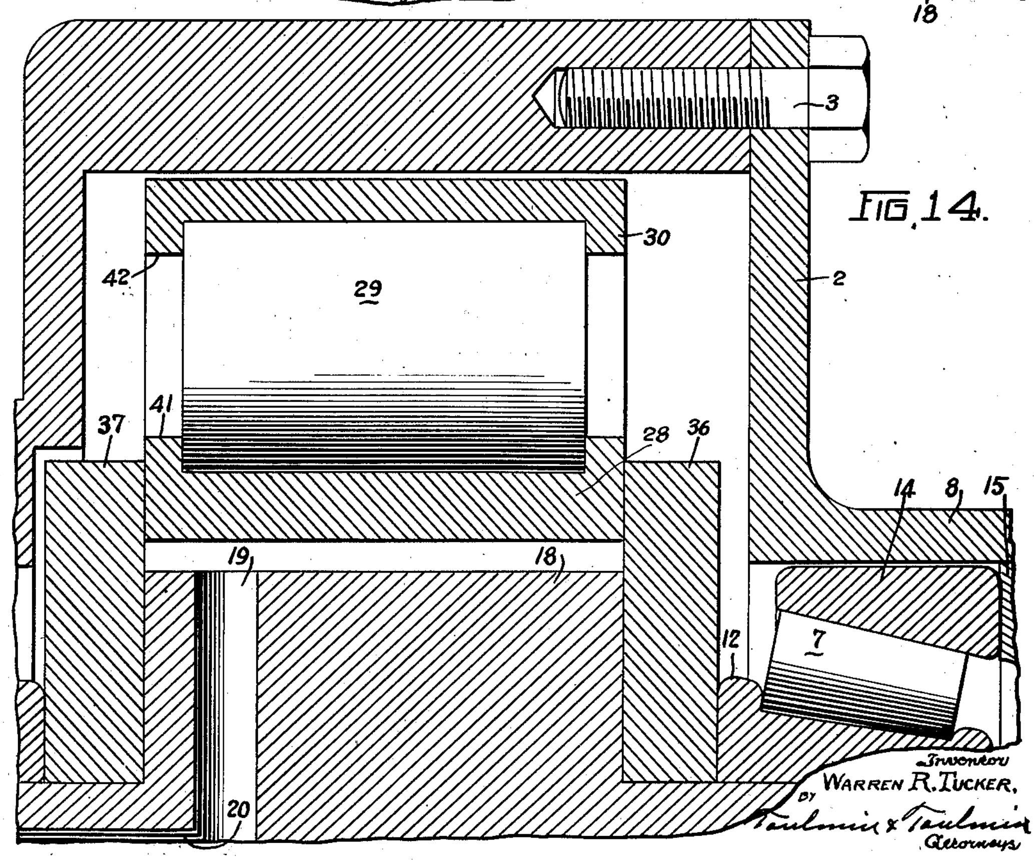


FIG. 14.

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UNITED STATES PATENT OFFICE

2,348,428

VARIABLE DELIVERY VANE PUMP

Warren R. Tucker, Dayton, Ohio, assignor to The Hydraulic Development Corp. Inc., Wilmington, Del., a corporation of Delaware

Application December 22, 1939, Serial No. 310,507

5 Claims. (Cl. 103—121)

This invention relates to a vane pump or motor, and more particularly to a vase device which when employed as a pump has variable delivery and, correspondingly, when applied as a motor has variable speed. In this specification, the device will be termed a pump but it is to be understood that the term "pump" includes a motor since the device can be operated as a motor if fluid under pressure is supplied to it. Accordingly, while the description refers to the device as a pump, it will be understood that the corresponding operation of the device as a motor with appropriate changes in the terminology employed, is contemplated. The pump of the present invention is particularly adapted to the supplying of a liquid under pressure, but it may be employed to compress a gas. For example, the device can be employed as an air compressor, or for compressing other gases. The description herein will relate particularly to devices which are especially adapted to the pumping of a hydraulic liquid such as oil or the like, as for example the hydraulic medium employed in the operation of hydraulic presses and related mechanisms.

The principal object of the present invention is to provide a vane pump which is of simplified construction, simple to assemble, and economical to construct, of increased mechanical efficiency whereby the power supplied makes available a larger amount of pressure fluid, and of reduced wear and maintenance; in a preferred embodiment, the pump is easily adjusted to take up such wear as occurs in the pump bearings.

Another object is to provide a vane pump in which the ring or cylinder which is eccentric to the rotor and which is normally stationary in the conventional vane pumps, rotates with the vanes and the rotor at substantially the same speed as the rotor, thereby eliminating the friction due to the vanes sliding on the inner periphery of the ring as in the ordinary vane pump; since this peripheral friction between the vanes and the cylinder or ring is increased by the action of centrifugal force on the freely radially movable vanes, and therefore goes up as the square of the speed of the rotor, the elimination of this friction by causing the cylinder to rotate with the vanes is an important factor in the increased efficiency and reduced wear of the vane pump of the present invention.

Another object is to provide a vane pump which is capable of making a variable delivery, the variation in the delivery being effected in a simple and convenient manner, this variation covering the range from no delivery to the maximum delivery in an infinitely variable manner.

Another object is to provide a vane pump in which the delivery is reversible in a simple and convenient manner, whereby the former inlet or suction side of the pump is converted to the pressure side and the former pressure side becomes the inlet or suction side.

Still another object is to provide a vane pump which is capable of infinitely variable delivery and which is reversible, the pump being capable of infinitely variable delivery in either mode of operation.

Still another object is to provide a pump in which the output is reversible by reversing the direction of rotation of the rotor, whereby the former inlet side of the pump is changed to a pressure side without the necessity for shifting the ring of the pump; this allows the pump to be manufactured in such manner that the shift ring is movable from the neutral position to the position of maximum delivery only in one direction.

Another object is to provide a vane pump in which the side walls of the pump are fixedly carried by the rotor and rotate therewith; this contributes materially to the reduction of friction since the friction between the rotor and vanes and the side walls is eliminated.

Another object is to provide a vane pump of the foregoing type wherein the ring or cylinder which the vanes contact is rollingly mounted, as for example, by being made the inner race of a roller or ball bearing, whereby the friction of the vanes against the ring is greater than the rolling friction of the ring against its rolling mounting, and, therefore, causes the ring to rotate with the vanes and rotor; in a preferred embodiment, the rolling mounting of the ring is made movable so as to thereby vary the eccentricity of the ring with respect to the rotor and to thereby vary the delivery of the pump or reverse its direction, or both.

It is another object of this invention to provide a complete assembly of rotor, the bearing assembly on the outside of said rotor and the distribution sleeve, all of which move together and can be adjusted together within the casing, longitudinally of the casing to accommodate wear and slight movement in operation. In this manner, the pump is self-accommodating in its moving parts to varied conditions of operation and to wear. Additionally, means is provided for adjusting the supporting bearings for this complete assembly and for simultaneously moving the rotor, its bearing assembly and the distribution sleeve together so that one adjustment will adjust all of the operating parts for wear.

It is a further object of this invention to provide bearings for supporting the shaft of the pump rotor, which bearings support the distribution sleeve in such a manner that the total diameter of the bearings is sufficient to support the distribution sleeve in spaced relationship to the casing with a sufficient clearance that any bending moment of the rotor shaft and of the distribution sleeve will not cause any binding between the sleeve and the pump casing, but at the same time the clearance is so small that a substantially fluid-tight engagement is maintained, particularly when pumping fluids such as oil, where the viscosity of the oil in combination with the slight clearance provided is sufficient to make a substantially fluid-tight seal and to lubricate the rotating distribution sleeve as it turns within the casing.

Still other objects of the present invention will more fully hereinafter appear and be readily apparent to those skilled in the art as the description proceeds.

In the accompanying drawings:

Fig. 1 is a transverse section taken on the line 1—1 of Fig. 2, of a pump embodying the principles of the present invention.

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

Fig. 3 is a transverse section on the line 3—3 of Fig. 2, looking in the direction of the arrows.

Fig. 4 is a fragmentary longitudinal section of the pump in Fig. 2 equipped with a pilot pump driven by the rotor of the main pump and mounted at the left-hand end of the pump of Fig. 2, this pilot pump being constructed in accordance with the principles of the present invention; this view shows how readily a pilot pump may be directly connected to the shaft of the main pump when the main pump is constructed in accordance with the present invention, because the shaft of the main pump is readily accessible, whereas in previous constructions the pump shaft has been inaccessible from one side of the pump.

Fig. 5 is a transverse section through the pilot pump shown in Fig. 4 on the line 5—5 of Fig. 4 looking in the direction of the arrows.

Fig. 6 is a transverse section similar to Fig. 1 of a modified form of pump in which the pump cylinder rollingly engages rolling elements which are adapted to rotate about a fixed center through the intermediary of a needle bearing; this view is taken on the line 6—6 on Fig. 7.

Fig. 7 is a sectional view taken on the line 7—7 of Fig. 6.

Fig. 8 is a longitudinal sectional view through a modified form of pump which is modified from that shown in Fig. 1 by having what is known as "pintle" valving.

Fig. 9 is a detailed sectional view on the line 9—9 of Fig. 8, and shows further details of the pintle valving.

Fig. 10 is a longitudinal section through a still further modification of pump which has been modified from the pump shown in Fig. 1 by having the valving at the side plate of the pump instead of on the pump shaft; this construction is particularly adaptable where the pump shaft is so small that the porting cannot be accommodated therein without unduly weakening the pump shaft.

Fig. 11 is a transverse section on the line 11—11 of Fig. 10, looking in the direction of the arrows.

Fig. 12 is a section on the line 12—12 of Fig. 11 looking in the direction of the arrows.

Fig. 13 is a fragmentary enlarged view of the left hand portion of the pump of Fig. 2, this view having the clearance between the left hand portion of the shaft and the pump housing greatly exaggerated for clarity.

Fig. 14 is a similar fragmentary enlargement of the middle upper portion of Fig. 2, showing in exaggerated form the clearances between the shift ring of the pump and the housing and between the right hand bearing and the supporting housing therefor.

General arrangement

The pump of the present invention comprises a rotor provided with radial ports leading from the periphery of the rotor to suitable valving mechanism associated with the rotor or with mechanism fixedly or integrally carried thereby for valving the ports in the rotor to the inlet side or to the pressure side of the pump. As the rotor rotates, the valving mechanism successively connects the successively presented ports in an appropriate manner so that the suction side of the pump is separated from the pressure side thereof.

The rotor is provided between each pair of ports with a freely radially slidable vane. These vanes define the suction and pressure chambers in the pump by cooperating with the pump cylinder which is disposed around the rotor and vanes. By shifting the eccentricity of this pump cylinder relative to the rotor, the amount or direction of delivery of the pump may be varied to suit the individual requirements.

The cylindrical ring of the pump is mounted so that it is free to rotate with the vanes and the rotor carrying the same, the speed of rotation of the cylinder being substantially uniform and substantially equalling the speed of the rotor. In a preferred form, the cylinder is rollingly mounted by making it the inner race of an anti-friction bearing such as a ball or roller bearing, whereby it is insured that the rolling friction of the cylinder with respect to the rolling elements of the bearing is much less than the friction between the vanes and the cylinder and consequently that the cylinder rotates with the vanes.

In a preferred form, the pump is made of the variable delivery type by making the outer race of the bearing just mentioned shiftable by mounting it so as to be transversely slidable in the housing of the pump. This outer race thus becomes the shift ring and by shifting this ring the pump cylinder may be varied in eccentricity with respect to the rotor by the provision of any suitable means for moving the outer race or shift ring transversely of the pump, whereby the amount or direction of delivery of the pump or both may be varied either manually or by suitable servo-motor means.

The suction and pressure chambers in the pump are sealed by side walls which are fixedly mounted upon the rotor and which consequently rotate therewith. These side walls are slidable relative to the pump cylinder and thus allow it to continuously assume its new position without destroying the seal between the side plates and the cylinder. The relative movement between the side walls of the rotor and the cylinder is very slight and the friction attendant thereupon is extremely small compared with the friction which is present in the ordinary vane pump in which the side walls are stationary relative to the rotor and rotor vanes. Thus the pump of the present invention in addition to eliminating the friction between the vanes and the cylinder also eliminates the friction between the rotor and vanes and the side walls of the pump.

From the foregoing, it will be seen that one of the principal features of the present invention is that of having the pump cylinder rotate with the rotor; in a preferred form, this cylinder is rollingly carried on an anti-friction bearing and in a still more preferred form is carried on a higher pairing (line or point contact) bearing in which rolling friction is present instead of a lower pairing (surface contact) bearing in which sliding friction is present. Any other means of allowing the cylinder to rotate freely so that its friction of rotation is lower than that of the friction between the vanes and the cylinder may be employed. For example, as will become apparent, the cylinder may be supported by and rollingly engaged with rollers which are free to rotate about a stationary pivot point and which themselves may be provided with suitable anti-friction bearings such as ball, roller, or needle bearings. It will further be seen as the description proceeds that the vanes are desirably truly radially disposed as distinguished from some vane pumps heretofore constructed in which vanes are mounted at an angle to the rotor. It will further be understood that suitable porting is provided in which the porting holes are large enough to prevent bubbling and other disadvantageous effects due to too high a velocity of the oil and the like through the ports. Where the pump shaft is sufficiently large in diameter to accommodate ports of the required size, they may be disposed in the shaft, and where the shaft is relatively small, the porting may be exterior of the shaft in a manner which will hereinafter appear.

Preferred form

In the preferred form shown in Figs. 1 to 3, the main housing of the pump is designated by reference numeral 1, this housing 1 being closed by the cover plate 2 which forms part of the housing and which is attached thereto by means of bolts 3. The pump shaft is designated as 4 and is carried on a tapered roller bearing 5 mounted within a reduced end portion 6 of housing 1, and by a similar tapered roller bearing 7 mounted within a flanged portion 8 of end plate 2. Bearing 5 comprises the inner race 9 which is fixedly mounted around an enlarged portion 10 of shaft 4, and an outer race 11 which is fixedly held within end portion 6 of housing 1. Correspondingly, the bearing 7 comprises an inner race 12 fixedly mounted around an enlarged portion 13 of shaft 4, and an outer race 14 which is received within the flanged portion 8 of end plate 2 and is free to slide longitudinally but which is normally stationary relative thereto by reason of the frictional engagement therewith. Outer race 14 is adapted to be pressed inwardly by a member 15 engaged by an adjusting member 16 which is threadably received within the outer portion of circular flange 8 and which is adapted to be rotated by the insertion of a suitable spanner wrench into the recesses 17 therein. In this way, outer race 14 of bearing 7 may be moved inwardly, causing a take-up of the wear in bearing 7 and causing inner race 9 of bearing 5 to be simultaneously moved leftwardly of Fig. 2, thereby taking up the wear in bearing 5. In this way, by one adjusting operation, the wear of the bearings 5 and 7 may be taken up.

Porting and valving

The rotor of the pump is designated as 18 and is formed integrally with shaft 4. As illustrated, this rotor 18 is provided with twelve radially disposed ports 19 which extend inwardly from its periphery into communication with corresponding axial bores 20 disposed in the enlarged shaft portion 10. These bores 20 merge with radial bores 21 in the left-hand end of shaft portion 10 as viewed in Fig. 2. As is seen from Fig. 3, these bores 21 are taken off in divided fashion, a portion of them being in communication with a conduit 22 in casing portion 6 through an annular zone 23. Another portion of radial bores 21 is in communication with a conduit 24 at the bottom of casing portion 6 through an annular zone 25.

Vanes

The rotor 18 is provided with a plurality of radial slots 26 extending inwardly from its periphery and located intermediate the ports 19. Mounted slidably in these slots 26 are the vanes 27 which are of a length equal to the length of the rotor 18 and which are of a width not greater than the depth of slots 26. In thickness, the vanes 27 are almost equal to the thickness of slots 26 so that while the vanes are free to move radially with respect to the rotor 18, they are sealed with respect thereto by reason of their close fit therewith. These vanes are adapted to be thrown radially outwardly as rotor 18 rotates by reason of the action of centrifugal force until they engage the pump cylinder presently to be described.

Pump cylinder

The cylinder or ring is designated as 28 and constitutes an inner race of the roller bearing, the rollers 29 of which roll upon the annular member 30 which is concentric with the cylinder 28 and which constitutes the outer race of the roller bearing thus formed. The outer race 30, and with it the rollers 29 and the cylinder 28, is shiftable transversely so as to vary the output of the pump, this being effected by making the shift ring 30 flat on its outer periphery on both the top and bottom as at 31, this flat surface 31 slidably cooperating with flat portion 32 on the interior of the housing 1 and at the top and bottom thereof. Transverse movement of shift ring 30 and corresponding movement of cylinder 28 is effected by the provision of shifting pins 33 and 34 slidably disposed at the right and left-hand of Fig. 1 within suitable bores provided therefor in casing 1. These pins 33 and 34 may be moved by any suitable means not shown, such as manual means or suitable servomotor means. These pins 33 and 34 serve to position the cylinder 28 and to thereby determine its eccentricity with respect to the rotor 18 and the amount and direction of delivery of the pump. As shown in Fig. 1, the cylinder 28 is moved all of the way to the left and accordingly, assuming clockwise rotation of rotor 18, the upper portion of the rotor is the delivery side, forcing the fluid inwardly through the ports designated A in Fig. 1, thence through longitudinal bores 20 and thence radially outwardly through the radial bores 21 designated B in Fig. 3, through annular collecting zone 23 into conduit 22 which is now the pressure conduit. At the same time, the lower portion of the pump in Fig. 1 is the suction side and causes fluid to be sucked in through conduit 24 which is now the suction or inlet conduit, thence through annular zone 25 into the radial bores designated C in Fig. 3, thence longitudinally through the corresponding axial bores 20 and through the rotor ports 19 which are designated D in Fig. 1 outwardly into the expanding chambers formed by the vanes 27, the rotor 18 and the cylinder 28.

In order to seal the intake side of the pump from the pressure side, those chambers in the pump which are not appreciably changing in volume at the instant considered are sealed off in the following manner. These chambers are in communication with the horizontally disposed rotor ports designated as E in Fig. 1. These ports E communicate with shaft ports F in Fig. 3 and at the instant considered, these shaft ports F are sealed off by their engagement with dividing projections 35 formed on the casing portion 6 intermediate of the annular zones 23 and 25 (Fig. 3). These projections 35 extend peripherally for a distance greater than the peripheral length of the radial bores 21, and are formed on their inner surface with a contour corresponding exactly to the periphery of the shaft portion 10.

Side walls

The side walls of the pump proper are designated as 36 and 37. These side walls are fixedly mounted on enlarged portions 13 and 10 respectively of shaft 4, as by means of shrinking, as illustrated in Figs. 1 to 3, or by other suitable means such as pinning thereto. Accordingdly, these side walls 36 and 37 rotate with the rotor 18 and form a tight fit therewith so as to prevent the leakage of fluid being pumped between the side walls and the rotor and shaft 4. These side walls 36 and 37 extend outwardly beyond the inner periphery of cylinder 28 and are in extremely close fitting but slidable relation therewith so that the cylinder 28 may move slightly relative to the walls 36 and 37 as rotation of cylinder 28 takes place, this movement being necessary in order to allow cylinder 28 to remain eccentric relative to rotor 18. The frictional engagement between cylinder 28 and side walls 36 and 37 is extremely small however because the shifting of cylinder 28 during rotation is not great and because the parts are so designed as to allow a minimum of friction at this point. In this way, the rotational frictional engagement between the rotor and vanes and the side walls 36 and 37 is eliminated and the friction of the pump is much less than the friction of vane pumps heretofore available in which the side walls were stationary and in which the cylinder was likewise stationary relative to the rotor and vanes thereon.

As a result of the foregoing construction, it will be seen that when the rotor 18 is rotated in a direction clockwise of Fig. 1, and with the shift ring 30 in the position shown in Fig. 1, fluid being pumped will be sucked in at conduit 24 and will be forced out at conduit 22 with very high efficiency of pumping, cylinder 28 rotating with the rotor 18 by reason of the very low rolling friction imposed between cylinder 28 and rollers 29 and between rollers 29 and shift ring 30.

General

As seen in Fig. 2, shaft 4 terminates short of the extreme left-hand portion of the casing 1 and the opening thus formed is covered by a removable plate 38 which provides access to the end of shaft 4. Plate 38 is mounted by means of bolts 38*a*. The left-hand end of shaft 4 is provided with a radially extending recess 39 for attachment of a pilot pump or other device to be driven by shaft 4 in a manner which will appear below. It will thus be seen that the preferred form of pump makes readily accessible both ends of the pump shaft, whereas in previous pumps the end of the shaft away from the driving end has not been accessible.

In order to prevent oil or other fluid being pumped from traveling along shaft portion 10 in excessive amounts, the grooves 40 seen at the left hand of Fig. 2 are provided thereon, one of these grooves being placed on each side of the inlet and outlet ports 22 and 24. When oil is the hydraulic medium being pumped, these grooves allow enough oil to escape to lubricate the bearing formed by members 28, 29 and 30 and the bearings 5 and 7. When a gas or nonlubricating liquid is being pumped, suitable means not shown may be provided for lubricating the various wearing parts and for maintaining the desired tight seal where required.

In order to retain the rollers 29 against excessive longitudinal movement, the cylinder 28 may be flanged as at 41 and the shift ring 30 may be similarly flanged as at 42.

From the foregoing, it will be seen that the inner race or cylindrical ring 28 absorbs the outward thrust of the vanes 27 and transmits it to the outer race or shift ring 30 and thence to the housing 1. The ring 28 is positioned longitudinally by the side walls 36 and 37 which are positioned by the bearings 5 and 7, and as bearings 5 and 7 are adjusted by means of the member 16, ring 28 together with rollers 29 and shift ring 30 move longitudinally, shift ring 30 being longitudinally slidable in housing 1 but being normally retained against rotation therein.

From Figs. 13 and 14 the magnitude of the clearances in several portions of the pump will be readily apparent. From Fig. 13 it will be seen that the clearance between the shaft portion 10 and the housing portion 6 therearound is of considerable magnitude so that this shaft portion 10 is free to rotate within the housing and is free to slide longitudinally therein upon adjustment of the bearings 5 and 7, and yet is sufficiently small that substantially no leakage therebetween occurs. The bearings 5 and 7 support the shaft of the pump in such a manner that this shaft portion 10 is free to rotate without binding even though a very large bending forces be applied to the pump shaft by reason of the pumping action. Fig. 13 further illustrates that there is no clearance between the outer race 11 of bearing 5 and the housing therearound and that there is likewise no clearance between the inner race 9 and the shaft portion 10.

Fig. 14 illustrates that there is considerable clearance between the shift ring 30 and the housing 1, so that the shift ring 30 is very free to move longitudinally upon the adjustment of the bearings 5 and 7. There is but slight tendency, of course, for the shift ring 30 to rotate and, therefore, this clearance may be extremely large. It is likewise not essential that a fluid-tight seal be made between the shift ring 30 and the housing 1, accordingly, the clearance at this point has been shown as being even greater than the clearance between shaft portion 10 and the housing portion 6. Fig. 14 further shows that there is a rather small clearance between the outer race 14 of bearing 7 and the cover plate 2 so that the race 14 is free to move longitudinally during adjustment but is retained against rotation by reason of the frictional engagement of the cover plate 2. Fig. 14 shows that there is no clearance between the inner race 12 and the shaft portion 13 and that there is also no clearance between the side walls 36 and 37 and the rotor 18, and that the clearance between the pump ring 28 and the side walls 36 and 37 is extremely small so that there is no leakage at this point.

Pilot pump

As is illustrated in Fig. 4, plate 38 referred to above may be removed and replaced with a plate 43 carrying a pilot pump which embodies the features of the main pump just described and which has a shaft 44, the end of which is flatted and is received in slot 39 in the left-hand end of shaft 4. Shaft 44 is rotatably carried on tapered bearings 45 in a manner similar to that in which shaft 4 of the main pump is journaled, an adjusting member 46 being provided as before for taking up the wear of these bearings 45. Shaft 44 integrally carries a rotor 47. Four pumping chambers are formed by four radial vanes 47*c* disposed similarly to the vanes 27 of the main pump and operating in a similar manner. The rotor 47 fixedly carries the side walls 47*a* and 47*b* which correspond to the side walls of the main pump. The side wall 47*a* is fixedly mounted upon shaft 44 as by being shrunk thereupon. The left-hand side plate 47*b* is integral with a sleeve 47*d* which is fixedly carried on shaft 44 as by shrinkage thereupon, and the porting is accomplished by locating the ports 47*e* outside of the shaft 44*a*, in the sleeve 47*d*. These ports 47*e* communicate with the right-angled ports 47*f* in the rotor. Thus, even though pump shaft 44 be small in diameter so that porting through it would so weaken it as to destroy its supporting function, porting is accomplished in a manner generally similar to that shown in Fig. 2. Valving is accomplished in the same manner as for the main pump of Figs. 1 to 3.

The vanes of the pilot pump carry with them a cylinder 48 which is the inner race of a ball bearing (as distinguished from the roller bearing used in the main pump) having balls 49 rollingly engaging an outer race or shift ring 50 which is transversely movable in the pilot pump casing 51 by means of rods 52 in a manner identical with that described above for the main pump. As illustrated in Figs. 4 and 5, the shift ring 50 of the pilot pump is shifted so as to deliver reversely from the main pump. For example, assuming clockwise rotation of the rotor 47 of the pilot pump (as viewed in Fig. 5), the pilot pump will suck in fluid through the upper conduit 53 and will deliver fluid under pressure through the lower conduit 54 of Fig. 4. It will thus be seen that the pilot pump can have its delivery adjusted both in amount and in direction, irrespective of the delivery of the main pump. It will further be seen that the pilot pump operates in the same manner as the main pump and that its delivery may be varied from a maximum to zero in either direction in infinitely small increments by shifting the shift ring 50, just as in the case of the main pump.

Modification with stationarily pivoted rollers

In the modified forms shown in Figs. 6 and 7, the general construction is similar to that described above in connection with Figs. 1 to 3 with the difference that the cylinder or ring 28 rollingly engages four spaced rollers 55 which are rotatable about fixed pivot points. These rollers 55 are in the form of hollow cylinders forming the outer race of a needle bearing which has rolling needle bearing elements 56 which roll upon an inner race 57 which is fixedly carried by, as by shrinking, a pin 58 which is fixedly mounted between a pair of annular side members 59, as by means of nuts 60, the intermediate portion of pin 58 being enlarged so as to form a spacer for the annular plates 59. The annular plates 59 are provided with a pair of oppositely disposed fixedly attached longitudinal side members 61 against which the shifting rods 33 and 34 for shifting the cylinder 28, engage. The members 59 and 61 form a shift ring for varying or reversing the delivery of the pump. The members 59 are flatted at 62 at their top and bottom, these flatted portions slidably cooperating with corresponding flatted portions 32 on the pump housing 1, as before, whereby by shifting rods 33 and 34 transversely, the eccentricity of cylinder 28 is varied without respect to rotor 18.

As a result of the foregoing construction, the cylinder or ring 28 is free to rotate with the rotor, there being rolling friction at the points where cylinder 28 contacts the rollers 55, and correspondingly rolling friction between the rollers 55 and the needle elements 56 and between the needles 56 and the inner races 57 which are fixedly carried in the shifting rings 59. Thus, the friction with which the vanes of the rotor engage the cylinder 28 is much greater than the friction attendant upon the rotation of cylinder 28 and the advantages of the construction shown in Figs 1 to 3 are attained.

Pintle valving modification

In the modification shown in Figs. 8 and 9, a pintle is employed to carry out the valving of the ports in the rotor. This entails the disadvantage that the side of the rotor opposite from the driving side is not accessible for the connection of other apparatus to be driven, since the stationary pintle occupies the space occupied by the left-hand portion of the rotor shaft in Figs. 1 to 3.

As shown in Figs. 8 and 9, the rotor-carrying shaft 4 is journaled in the end plate 2*a* by means of oppositely directed roller thrust bearings 63. The right hand rotor side wall 36*a* is integral with the driving shaft 4 and is pinned to the rotor 18*a* by means of cap screws 64. The left-hand side wall 37*a* is fixedly attached to and carried by the rotor 18*a* by means of the cap screws 65 and the retaining ring 66. The left hand end of the housing 1*a* is closed by a member 6*a* which has a flanged portion 6*b* which forms the left-hand end wall for the pump.

A stationary pintle 67 is slidably but tightly mounted in the casing member 6*a* and has a somewhat reduced portion extending through an axial bore in the rotor 18*a* with an extremely close but slidable fit. The rotor is journaled upon the pintle 67 by means of the tapered roller bearings 68 and 69. The left hand roller bearing 69 has its outer race 70 clamped between the ring 66 and the rotor 18*a* and its inner race 71 bearing on the left hand against a ring 72 which bears against the inward face 73 of member 6*a*. The right hand roller bearing 68 has its outer race 74 fixedly held between the side wall 36*a* and the rotor 18*a* in a suitable recess in the latter, and has its inner race 75 engaging on its right side a plate 76 fixedly carried on the right hand end of the pintle 67.

Thus, by pulling the pintle 67 leftwardly to the necessary extent, wear and slack in the bearings 68 and 69 may be taken up, plate 76 pushing the inner race 75 of bearing 68 leftwardly, and thereafter pushing rotor 18*a* and the outer race 70 of the bearing 69 leftwardly, the inner race 71 of bearing 69 being positioned by reason of its abutting against the ring 72 which in turn abuts against and is positioned by the inward end 73 of the member 6*a*.

In order to pull the pintle 67 leftwardly to make this adjustment, its left-hand end is provided with a threaded portion which extends leftwardly of member 6*a* and on which is threadedly received an adjusting nut 77 which engages the outward face 78 of member 6*a*, and which is split on one side and adapted to be locked against rotation by tightening a bolt 79 on the split side. Tightening of bolt 79 draws the two split halves into locked relationship with respect to the threads on the end of the pintle 67 and prevents rotation of the nut 77 with respect to the pintle 67. Thus, by loosening locking bolt 79, turning nut 77 up on the pintle 67 until the clearance or wear has been taken up, and tightening the locking bolt 79, the pintle is adjusted leftwardly and is fixedly positioned in its adjustment.

In order to prevent the pintle from rotating, a slot 80 may be provided in its end portion, this slot engaging a suitable key (not shown) carried by the member 6*a*. The end of the pintle is protected by a cap plate 81 carried by the member 6*a*. A drainage port 82 may be provided in cap plate 81 for carrying off oil which escapes along the pintle to the space in the plate 81.

The pintle 67 is cylindrical and is provided with four collecting bores 83 which extend parallel to the axis of the pintle, and at the left-hand end of these bores 83 with four radial bores 84, the upper two of which extend into communication with a conduit 22*a* in the member 6*a*, and the lower two of which extend into similar communication with a conduit 24*a*. Either of conduits 22*a* or 24*a* is adapted to function as an inlet or as an outlet conduit.

The valving of the pressure and suction chambers formed between the rotor 18*a* and the ring 28 is accomplished as follows. The pintle 67 is cut away adjacent the radial ports 19*a* in the rotor 18*a*, in the manner indicated in Figs. 8 and 9. This cutting away involves cutting radially inwardly on the surface of the pintle 67 so as to form a cross-shaped cross-section having two projections 85 which are adapted to seal the horizontal ports 19*a* which are designated E in Fig. 9. The vertical projections 86 are flatted on their outward face so as to allow free communication between all of the upper ports A or between all of the lower ports D and yet to exert a reinforcing action so that the pintle 67 is not appreciably weakened at this point.

Thus, for example, the upper ports A may act as suction ports while the lower ports D act as pressure ports and the ports E are sealed off so as to separate the discharge side of the pump from the intake side. It will be understood, of course, that the ports are successively shifted by their engagement with the projections 85 as the rotor 18*a* rotates. It will further be seen that all of the radial ports A are in communication with one another and in communication with either of the upper axial bores 83, and that the same is true of all of the radial ports D.

Modification with valving through side wall of rotor

In Figs. 10 to 12, there is portrayed a modification of the invention wherein the valving of the pump chambers is effected through the side plate of the pump. The pump arrangement is in general along the lines of that in the embodiment of Figs. 1 to 3, the rotor 18*b* being integral with the pump shaft 4*b* which has an enlarged portion 13*b* journaled within a bearing 7*b*, and a reduced left-hand portion 10*b* which is journaled in a bearing 5*b*. Bearing 5*b* is carried within a member 6*c* which is bolted to the main pump casing 1*b* by bolts 3*b*. The bearings 7*b* and 5*b* are adjusted by a member 16 in the same manner as that described above in connection with Figs. 1 to 3.

The rotor 18*b* has the radially extending ports 19*b* which correspond to the ports 19 in Figs. 1 to 3 and which merge with horizontal axial ports 87 which connect with coaxial ports 88 formed in the left-hand side wall 37*b* which is fixedly and tightly secured to the rotor 18*b* as before.

Ports 88 extend outwardly through an annular boss 89 which is integral with side wall 37*b* and which is slidably received in an annular groove 90 formed in a stationary collecting plate 91 fixedly mounted between the cap plate 6*c* and the casing 1*b*, the rightward edge of plate 91 being indicated as 91*b*.

The plate 91 serves to take off the intake and discharge and to keep the intake separate from the discharge. In order to accomplish this, the plate 91 has a generally radially extending passageway 92 which is in communication with the lower ports 88, and a similar passageway 93 in its upper portion which is in communication with the upper ports 88. Passageway 93 at its outward portion is in communication with conduit 95 while passageway 92 is in similar communication with a conduit 96, conduits 95 and 96 being formed in the cap plate 6*b* and being adapted to function either as inlet or outlet conduits, depending upon the direction of delivery of the pump. An annular passageway 94 which has its center line coincident with the groove 90, at all times connects passageways 92 and 93 with the upper and lower ports 88, respectively.

Separation of the inlet side of the pump from the outlet side is accomplished by the provision of a pair of sealing members 97 adapted to seal the two ports 88 which are horizontal. As indicated in Fig. 12, these members 97 are cup-shaped and have a flat rightward sealing face and are yieldingly pressed into engagement with the rotating plate 37*b* by a spring 98 which is interposed between the member 97 and a cup-like receiving member 99 mounted in a wall 91*a* of the plate member 91. The sealing member 97 is tightly but slidably received within the member 99 so that a seal exists at all times therebetween. Thus member 97 is free to move relative to fixed plate 91 during the longitudinal adjustment of the rotor 18*b* by means of the member 16 to take up wear of the bearings thereof, and at the same time to maintain perfect sealing contact over the horizontal ports 88 and to maintain a perfect seal between the passageways 93 and 92. The sealing members 97 are disposed in such manner as to cover the groove 94, as is indicated in Fig. 11 and thus to prevent pressure liquid from intermingling with the suction liquid.

The modification shown in Figs. 10 to 12 is particularly advantageous where it is desired to use a pump shaft of small diameter where the introduction of ports in the pump shaft, as in Fig. 2, would unduly weaken the shaft. In the modification shown in Figs. 10 to 12, valving is carried out exclusively through the side walls of the pump and outwardly of the pump shaft so that it is not necessary to bore the pump shaft. This construction is particularly advantageous in the case of small pumps such as pilot pumps.

From the foregoing, it will be seen that the present invention provides a continuously variable reversible vane pump of improved efficiency and simplicity of construction, in which the friction is reduced to a minimum and in which wear is correspondingly reduced. It will further be seen that the present invention provides for the substantially complete elimination of sliding friction of vane pumps heretofore produced. It will further be seen that the invention provides for the adjustment of the pump to take up wear by a single simple adjusting step.

Numerous other advantages of the pump of the present invention will be obvious to those skilled in the art.

I wish it to be understood that I intend to include as within my invention such modifications and adaptations thereof as will be obvious to those skilled in the art and as fall within the terms or the spirit of the appended claims.

Having thus fully described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A vane pump comprising a pump housing, a support member carried within said housing and forming the outer race of an anti-friction bearing, a cylinder ring positioned within said support member and forming the inner race of the anti-friction bearing, a plurality of rotating bearing members disposed between said support member and said cylinder ring to permit free rotation of said cylinder ring, a rotor positioned within said cylinder ring normally eccentrically with respect thereto and forming a fluid working space therebetween, said working space having fluid inlet and outlet ports therefor, means to rotate said rotor, a plurality of vanes extending between said rotor and said cylinder ring, a shaft normally fixedly positioned in said housing but axially adjustably movable therein and extending within said rotor normally eccentrically with respect to said cylinder ring, bearing means carried within opposite faces of said rotor and upon said shaft for supporting the rotor upon said shaft, each of said bearing means comprising an outer race, an inner race and a plurality of rotary bearing elements, end plates secured to said rotor for engaging said cylinder ring and for securing said shaft bearing means within said rotor, means extending through said housing to engage said support member for shifting the same transversely of the axis of said cylinder ring to thereby change the eccentricity between said cylinder ring and said rotor, means for axially moving said shaft, and means engaging the inner races of the bearing means on said shaft to cause relative movement between said inner and outer races longitudinally with respect to each other and with respect to the axis of the shaft upon longitudinal movement of the shaft to reduce the clearance between the elements of said bearing means on said shaft; said rotor, said cylinder ring and said support member following the longitudinal movement of said shaft to maintain the same working relationship therebetween as existed prior to adjustment of said bearing means on said shaft.

2. A vane pump comprising a housing having an internal chamber open at both ends, a shift ring supported within said housing for movement transversely with respect to the axis of said housing and forming the outer race of an anti-friction bearing, a cylinder ring positioned within said shift ring and forming the inner race of the anti-friction bearing, a rotor positioned within said cylinder ring normally eccentrically with respect thereto, a plurality of vanes extending from said rotor into engagement with said cylinder ring to form a plurality of compression chambers, bearing means positioned within opposite sides of said rotor, each of said bearing means comprising an inner race, an outer race and a plurality of rotary bearing elements therebetween, end plates secured to opposite sides of said rotor engaging the outer races of said bearing means and said cylinder ring, an end wall for said housing, a rotor supporting shaft supported in said end wall normally eccentrically with respect to said cylinder ring, said shaft extending through said bearing means in said rotor to support said rotor, an end wall for the end of said housing which is opposite said shaft having bearing means therein, a shaft extending from the rotor end plate adjacent said end wall and being supported in said last-named bearing means, port means extending through said rotor in communication with said chambers, port means extending longitudinally through said support shaft and communicating with said rotor port means, and port means in the end wall supporting said support shaft communicating with said port means in said shaft for providing an inlet and an outlet to said chambers.

3. In a vane pump a housing providing a chamber therein, a shaft supported by a wall of said housing and extending into the chamber provided by said housing, a rotor, bearing means positioned in opposite sides of said rotor, each of said bearing means comprising an inner race, an outer race and a plurality of rotary bearing elements therebetween the clearance between said bearing elements being adjustable by displacement of said bearing races relative to each other, means for retaining the outer races of said bearing means in said rotor, means engaging the inner races of said bearing means to cause relative movement between said inner and outer races upon longitudinal movement of said shaft, said shaft being movable longitudinally with respect to the axis thereof to cause said relative movement between said inner and outer races to thereby reduce the clearance between said bearing elements and races to zero and maintain a concentric clearance area between said shaft and said rotor greater than the total clearance provided in said bearing means but sufficiently small that a liquid seal is provided therebetween by means of the lubricating liquid provided within the pump whereby said rotor is floatingly carried upon said shaft, a rotatable cylinder associated with said rotor normally eccentrically with respect thereto, vanes between said rotor and said cylinder, fluid flow passages for conducting fluid to and from said cylinder, and end plates secured to said rotor for engaging said cylinder which rotates therewith, the clearance between said

end plates and said cylinder being less than the clearance between said rotor and said shaft whereby a fluid tight sliding relationship is provided between said end plates and said cylinder without dependence upon a liquid seal therebetween by means of the lubricating liquid to prevent escape of high pressure fluid from said cylinder.

4. In a vane pump a housing providing a chamber therein, a shaft supported by a wall of said housing and extending into the chamber provided by said housing, a rotor, bearing means positioned in opposite sides of said rotor, each of said bearing means comprising an inner race, an outer race and a plurality of rotary bearing elements therebetween the clearance between said bearing elements being adjustable by displacement of said bearing races relative to each other, means for retaining the outer races of said bearing means in said rotor, means engaging the inner races of said bearing means to cause relative movement between said inner and outer races upon longitudinal movement of said shaft, said shaft being movable longitudinally with respect to the axis thereof to cause said relative movement between said inner and outer races to thereby reduce the clearance between said bearing elements and races to zero and maintain a concentric clearance area between said shaft and said rotor greater than the total clearance provided in said bearing means but sufficiently small that a liquid seal is provided therebetween by means of the lubricating liquid provided within the pump whereby said rotor is floatingly carried upon said shaft, a rotatable cylinder associated with said rotor normally eccentrically with respect thereto, vanes between said rotor and said cylinder, fluid flow passages for conducting fluid to and from said cylinder, end plates secured to said rotor for engaging said cylinder which rotates therewith, the clearance between said end plates and said cylinder being less than the clearance between said rotor and said shaft whereby a fluid tight sliding relationship is provided between said end plates and said cylinder without dependence upon a liquid seal therebetween by means of the lubricating liquid to prevent escape of high pressure fluid from said cylinder, and rotary bearing elements in engagement with said cylinder for supporting the same, said last-named rotary bearing elements having an outer race in engagement with said housing shiftable within said housing to change the eccentric relationship between said cylinder and said rotor, the total clearance between said last-named rotary bearing elements, said cylinder and said last named outer race being substantially zero to maintain accurate alignment of said cylinder between said end plates and accurate concentricity or eccentricity of said cylinder relative to said rotor, while the bearing clearance between said last named outer race and said housing is greater than the clearance between said rotor and said shaft to permit complete freedom of movement of said last named outer race within said housing longitudinally and transversely with respect to the axis of said shaft when shifting of the outer race to thereby change the eccentric relationship between said cylinder and said rotor and when adjusting the clearance of the bearing elements supporting said rotor.

5. A pump comprising a housing, a rotor rotatably mounted therein means to rotate said rotor, a pump cylinder ring surrounding said rotor and normally eccentric thereto, vanes between said cylinder ring and rotor said cylinder ring and rotor forming a fluid working chamber therebetween, fluid inlet and outlet means for said working chamber, shift ring means surrounding said cylinder ring, rotatable bearing means disposed between said cylinder ring and said shift ring for allowing said cylinder ring to freely rotate within said shift ring and with said rotor, said shift ring engaging said housing so as to be longitudinally and transversely movable therein with respect to the axis of said shift ring but normally non-rotatable therein, a non-rotatable shaft for said rotor carried by said housing and movable longitudinally with respect to the axis thereof, side wall means secured on each side of said rotor engaging said cylinder ring in fluid tight but sliding engagement therewith and for retaining rotor bearing means in said rotor, a bearing on said shaft on each side of said rotor positioned within said rotor and retained therein by said side wall means, each of said bearings comprising an inner race engaging said shaft and an outer race engaging said rotor, the clearance of said bearings being adjustable by axial displacement of said races with respect to each other, said outer races being fixedly positioned in said rotor against longitudinal movement therein, and means engaging said inner races and engaged by said shaft for moving said inner races longitudinally toward said outer races whereby to take up wear and slack in said bearings and to simultaneously position longitudinally said rotor, said side wall means, said cylinder ring and said shift ring within said housing and axially upon said shaft upon longitudinal movement of said shaft.

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