June 6, 1961 E. H. BOWERS ET AL 2,987,006

ROTATING SEALS FOR USE WITH HIGH PRESSURE LIQUID

Filed May 7, 1957

2 Sheets-Sheet 1

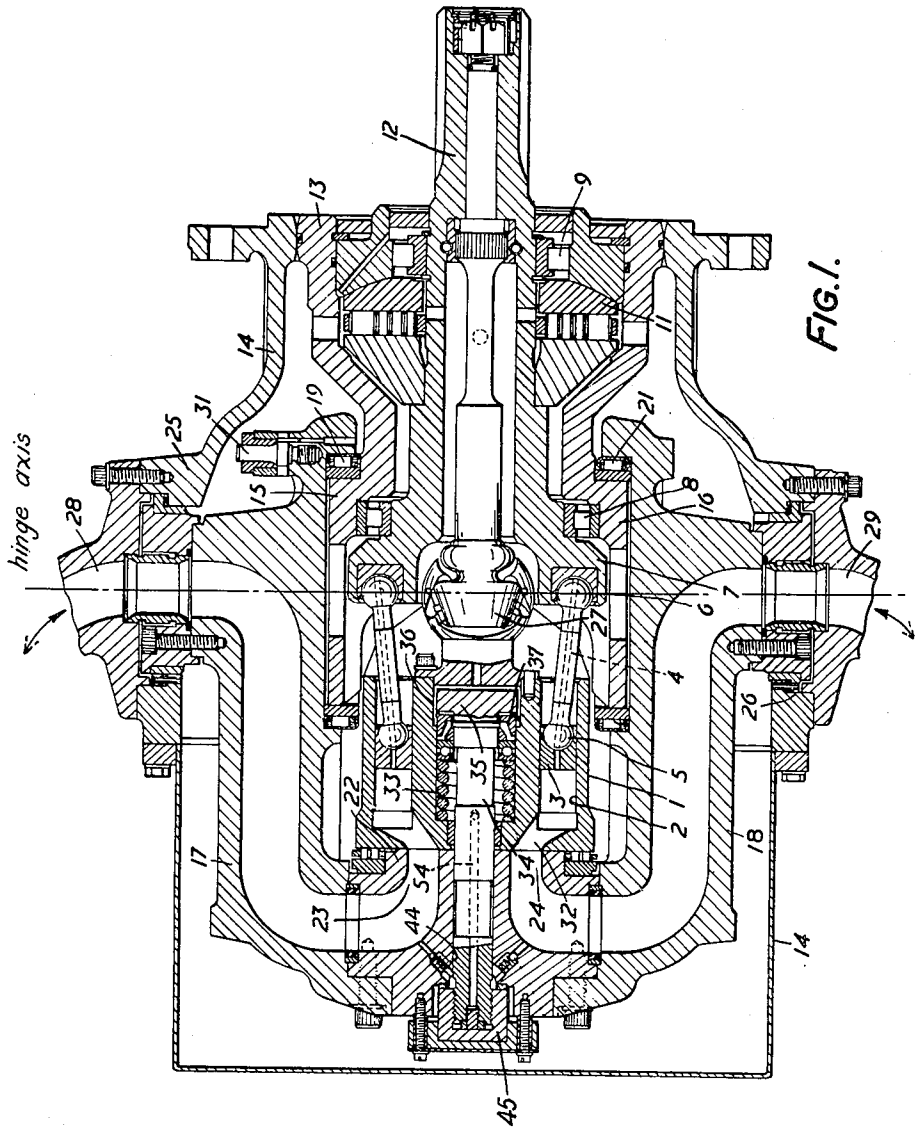

FIG. 1.

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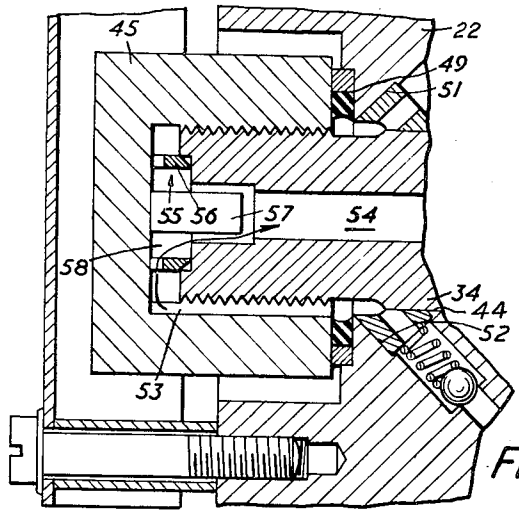

FIG. 2.

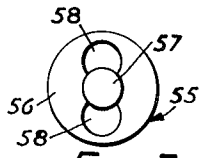

FIG. 3.

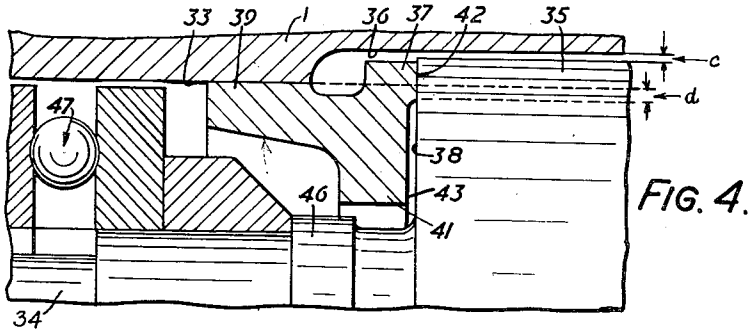

FIG. 4.

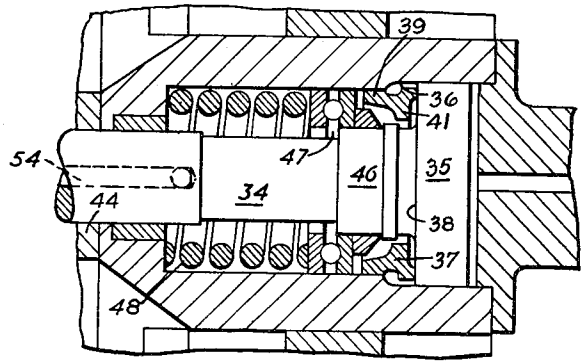

FIG. 5.

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ROTATING SEALS FOR USE WITH HIGH PRESSURE LIQUID

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9 Claims. (Cl. 103—162)

This invention relates to hydraulic pumps or motors of the kind in which a rotating cylinder block including regularly angularly spaced displacement cylinders located parallel or approximately parallel to the rotation axis, rotates on a valve plate, and a centrally placed balancing piston and cylinder or the equivalent means acts between the cylinder block and the valve plate to urge the block into contact with the valve plate to counteract the hydraulic separating force acting between the valve plate and block. In this kind of pump or motor the balancing cylinder is usually fed with pressure liquid from the pressure port in the valve plate and one necessity in order to get high efficiency is to reduce leakage past the balancing piston to a minimum.

The object of this invention is to provide a pump or motor of the kind set forth in which the balancing piston is sealed in its cylinder in a substantially liquid-tight manner at the working pressure whilst at the same time permitting relative rotation. A further object is to provide such a seal which is extremely reliable in operation and automatically adjustable to compensate for wear that may take place during substantially the whole working life of the pump or motor, for it is in a location that would require disassembly of the pump or motor in order to renew the seal.

In accordance with the present invention, a pump or motor of the kind referred to is formed with an axially disposed balancing cylinder or recess within its cylinder block, wherein an abutment affixed to the valve plate is disposed, the abutment dividing such recess into a chamber nearer the valve plate and a chamber distant therefrom. To prevent any appreciable leakage between the chambers and to develop pressure in such nearer chamber, whereto hydraulic fluid is admitted from the high pressure port, a circular seal of a special form and arranged in a special disposition, is interposed between the abutment and a surface of the balancing cylinder. Since the nearer chamber is subjected to the high pressure and the distant chamber communicates with a much lower pressure region, an excessive force would be developed to urge the rotative cylinder block onto the non-rotative valve plate and to urge the seal against surfaces of the rotative cylinder block and of the non-rotative abutment, except for the special disposition referred to with which this invention is concerned. The excessive pressure would produce excessive and rapid wear in relatively inaccessible locations. The effect of the special disposition of this invention is to reduce the effective area upon which the pressure difference is active to an area so small that the total pressure is only so much as is required to effect adequate sealing throughout the life of the device between the rotative cylinder block and the nonrotative valve plate. In the form illustrated the special disposition involves a skirted circular seal ring of metal or like hard material, the skirt whereof fits in an accurate liquid-tight manner against the wall of the balancing cylinder, and the seal also being pressed liquid-tightly against a transverse surface of the abutment on a substantially circular seating, to leave a portion of the abutment, of slightly smaller area than the effective cross-section of the balancing cylinder, exposed to the pressure in the latter. Thereby the hydraulic pressure, although it may be high, can only act over the small area difference, to urge the seal, which rotates with the cylinder block against which its skirt is pressed, against the non-rotative abutment with a light enough force to avoid material wear. The special disposition described is the one preferred, but others are possible.

It is preferred that the seal's skirt should have a wall sufficiently thin that pressure within the balancing cylinder or recess can expand it slightly to make highly effective sealing contact with the cylinder. Still further, it is preferred that the seal should extend from the cylinder into an enlargement thereof so that the circular seating may extend to a diameter slightly larger than the cylinder diameter to the extent that the force developed by the pressure of leakage liquid under the seating only reduces, but does not overcome the hydraulic force acting to retain the seal in contact with the abutment. A very small amount of leakage past the seating is desirable in order to reduce the rate of wear on the seating and by trial and error selection of the area of the abutment enclosed by the seating and the area of the seating it is possible to reduce leakage to a very small amount and still retain a lubricating liquid film between the seating and the abutment. Still further, it is preferred that the pressure liquid fed to the balancing cylinder should be thoroughly filtered so that no particles of abrasive material may be carried by the liquid to the seal.

The above describes the form illustrated, which, however, is not the only practicable form, so that speaking generally, the invention involves the employment between one surface of an abutment of the nature described, and one surface of the cylinder divided thereby, of a specially formed and arranged seal ring. One such surface, whether of the cylinder or of the abutment, is cylindrical, and is engaged by the skirt of a skirted seal ring in a manner to be urged by existing pressure substantially liquid-tightly thereto; the other such surface, of the abutment or of the cylinder, is engaged by a slight annular seating at an end of the seal ring, and, by a small pressure difference generated by the same pressure and acting on the slight annular seating, is urged tightly enough against the transverse surface whereon the annular seating bears to prevent substantial leakage and to maintain seating pressure, but with insufficient force to produce material wear.

In order that the invention may be clearly understood one embodiment thereof for use as a variable stroke hydraulic pump will be described with reference to the accompanying drawings, in which:

FIGURE 1 is a cross-section through the pump,

FIGURE 2 is an enlargement of the part of FIGURE 1 showing a filter,

FIGURE 3 is an end view of the filter,

FIGURE 4 is an enlarged view of the balancing cylinder shown in FIGURE 1, at the location of the seal ring, and

FIGURE 5 is a somewhat smaller detail view of the entire balancing cylinder of FIGURE 4, showing the relationship of the parts to the sealing ring.

The pump comprises basically a rotating cylinder block 1 having a plurality of displacement cylinders 2 lying parallel to the axis of block rotation regularly disposed around this axis. In each cylinder a piston 3 is located from which a connecting rod 4 extends, being connected to the piston by means of a ball joint 5. The outer ends of the connecting rods 4 are located by means of ball joints 6 at regularly spaced intervals around a rotary thrust plate 7, constituting one form of end thrust means.

The thrust plate is located radially by means of roller bearings 8 and 9 whilst the axial thrust is taken by a thrust bearing 11. A drive shaft 12 integral with the thrust plate extends from the pump. The thrust plate is carried by its bearings in a fixed housing 13 which in turn is located in a pump casing 14. The housing 13 extends into casing 14 and terminates in a pair of discs 15 and 16 both located on an axis transverse to the axis of the shaft 12. A pair of hollow arms 17 and 18 are secured one on each of the discs 15 and 16 by means of roller bearings 19 and 21. These arms are connected to a valve plate 22, the hollow passages in the arms leading into ports 23 and 24 located in the valve plate. Adjacent the discs 15 and 16 the arms 17, 18 extend outwardly into bearings 25 and 26 formed in the casing 14. The axes of the bearings 25, 26 and of the discs 15 and 16 coincide so that the arms, valve plate and rotating block may be moved angularly about this axis in order to vary the stroke of the pistons 5 in cylinder 2 during rotation of the shaft 12, thrust plate 8 and cylinder block 1. This axis will be referred to as the hinge axis. A universal joint 27 of a constant velocity type interconnects the thrust plate and the cylinder block to ensure that they rotate together. The geometric centre of the universal joint 27 is arranged to lie on the hinge axis whilst the circle which includes the centers of the ball joints 6 in the thrust plate is so arranged that the hinge axis passes through a diameter. In the bearings 25 and 26 connection from the hollow arms is made to external passages 28 and 29 whereby pumped liquid may enter and leave the pump, the direction of flow depending on the angular displacement of the cylinder block, valve plate and hollow arms about the hinge axis. For variation of the displacement a pin 31 is secured to the hollow arm 17 and is connected by means of a screw mechanism (not shown) to the casing. By this means the angular position of the cylinder block, valve plate and hollow arms may be adjusted about the hinge axis.

The surface of the cylinder block 1 which contacts the valve plate 22 includes a plurality of ports 32 extending one from each cylinder 2. These ports are located at a position radially inwards of the cylinder position in order that the area of ports 23 and 24 in the valve plate may be kept to the smallest possible dimensions whilst still providing liquid flow passages which will not unduly restrict flow. Whilst this arrangement materially reduces the effective area of the ports 23 and 24, it cannot reduce the area of the ports 23 and 24 so that they are less than the total area of the cylinders which connect into them at any one time, with the result that whilst the pump is working there is always a predominating hydraulic force tending to lift the cylinder block from the valve plate. This force is of course greatest at the delivery port which may be one or the other of ports 23 and 24 depending on the direction of the angular displacement about the hinge axis. In order to maintain the cylinder block in contact with the valve plate under all conditions a central balancing cylinder 33 is provided in the cylinder block 2 and in this cylinder a rod 34 is located being secured in the valve plate 22. This rod 34 extends throughout the balancing cylinder and terminates in a piston or head 35, which is in effect a fixed abutment element. The head 35 is located outside the cylinder 33 in an enlargement 36 of the cylinder. A circular sealing ring 37 is located at the end of the cylinder 33 and bears against the flat undersurface 38 of the enlarged head 35. The seal 37 includes a thin-walled cylindrical wall portion or skirt 39 which is a close fit in the cylinder 33. This wall 39 is integral with a reinforcing ring 41 which includes at the outer edge of its transverse end a circular seating surface 42 which makes contact with the face 38. The inner edge of the seating surface 42 is arranged to be slightly smaller in diameter than the cylinder 33 whilst the outer edge of the surface 42 extends into the recess 36 and is slightly larger in diameter than cylinder 33 to form the surface 42; see FIGURE 4. The reinforcing ring 41 is relieved at 43 on the surface adjacent to the surface 38. The dotted lines extended on FIGURE 4 from the cylinder 33 and the inner diameter of the seating 42 illustrate the small difference *d* in diameter.

By means of the abutment 35 and the sealing ring 37 the balancing cylinder or chamber is effectively divided into the large chamber at the left of the abutment, pressurized in a manner to be explained shortly, and the small chamber at the right of the abutment, which as it communicates with a low pressure region is at less pressure than the left hand chamber. It should be noted that the portion of the recess 36 at the left of the abutment 35 and radially outward of the sealing ring 37 is, in effect, a part of this low pressure region, since it is in communication therewith by way of the clearance space *c*, and is sealed off by the sealing ring seating at 39 and at 42 from the pressurized region.

The rod 34 is located accurately in a bore 44 in the valve plate 22 and is retained in position by means of a capped nut 45 in screw-threaded engagement with the outer end. Interiorly of the cylinder 33 a shoulder 46 is provided on the rod 34 against which a thrust ball race is located, the ball 47 being shown in FIGURE 4. A spring 48 acting between the inner end of the cylinder 33 and the thrust ball race serves to retain the rod 34 such that the nut 45 engages the rear of the valve plate 22. A seal 49 between the nut 45 and valve plate 22 serves to prevent leakage of pressure liquid. Two passages 51 and 52 extend one from each of the ports 23 and 24 to the space enclosed by the seal 49. A slot 53 extending through the screw thread in nut 45 carries pressure liquid to the end of the rod 34 so that access may be had to an axial hole 54 extending through the rod and terminating in cylinder 33. In between the capped end of nut 45 and the end of rod 34 a magnetic filter assembly 55 is located. This comprises a brass disc 56 in which a bar magnet 57 is fixed centrally, passages 58 being provided whereby liquid which enters into the hole 54 must pass over the magnet 57. In this way any particles of a ferrous nature in the liquid are retained. The passages 51 and 52 each include non-return valves whereby only liquid from the port 23 or 24 which is at the higher pressure can enter the hole 54.

When the pump is in operation and the cylinder block and valve plate have been displaced angularly about the hinge axis, pressure liquid will be delivered at one of the ports 23 or 24. This pressure liquid will in the main pass out from the pump through the passages 28 or 29 for its intended use, but a very small quantity will enter through the passage 54 into cylinder 33. This pressure will act on the seal 37 to urge its annular seating 42 against the face 38 by virtue of the small difference *a* in cross-sectional area between the wall 39 and the inner diameter of the seat 42. Although the pump is intended to work at extremely high pressures it will be seen that the force that can be exerted on the seat 42 is quite small, but at the same time bears a definite proportion to the working pressure. The enlargement 36 of the cylinder is in connection with low pressure by virtue of a small, exaggeratedly shown, clearance *c* existing between the head 35 of rod 34 and the enlargement 36 and the seat 42 is therefore positioned to seal between high and low pressure liquid. A very small leakage is desirable in order that the seat 42 should not bear directly on the face 38 and the dimensions of the wall 39 and the seat 42 are adjusted so that a very small hydraulic force urges the seating 42 against face 38. The fact that liquid leaks across the seating 42 means that a pressure gradient exists and a hydraulic force is exerted on the seat 42 which is taken into consideration and must be such that the hydraulic force urging the seat 42 into engagement is never overcome, there always being a slight force tending to maintain the seal with the seating 42 against the face 38. In addition, the pressure acting on wall or skirt 39 will expand it slightly into liquid-tight engagement with cylin-

der 33 and at the same time cause a substantial friction grip to be exerted, for the bearing surfaces are of relatively large area. Thus the seal will rotate with the block 1 and the seat 42 will rotate on the face 38.

Thus, when the pump is operating a hydraulic force exerted on the cylinder block at the end of cylinder 33 always acts to ensure that the cylinder block remains in sealing contact with the valve plate 22 with a very small predominating force such that in spite of high operating pump pressures there is no tendency for the cylinder block to lift from the valve plate. The cylinder 33 and the seal 37, which are principally the means to ensure this balance, are arranged as described above so that there is only a very small leakage which does not cause any measurable loss in efficiency of the pump. The sealing ring 37 always takes up a position to ensure a substantially liquid-tight seal quite independently of any wear which may have taken place between the seat 42 and the face 38 whereby the seal has a long life. In effect it can be constructed to last as long as the pump itself without replacement or adjustment.

We claim as our invention:

1. A hydraulic rotary assembly of the character described, comprising in combination a rotative cylinder block, axially directed displacement cylinders formed in said cylinder block at angular spacings about the rotative axis, ports formed in a transverse end face of the cylinder block each communicating with its respective cylinder, a non-rotative valve plate abutting such end face, an intake port and a pressure port in said valve plate arranged for cooperation with said ports in the cylinder block, for intake and discharge, respectively, of hydraulic fluid, a piston reciprocable in each cylinder, a thrust plate rotative conjointly with said cylinder block and disposed in use at a hinge angle to such rotative axis, and operatively connected to said pistons to effect their reciprocation during rotation of the cylinder block, an axially located and directed balancing cylinder formed in said cylinder block, closed at its end nearer the valve plate, but communicating at this end by a flow path with said pressure port, and at its opposite end with a low pressure region, an abutment element formed with a transverse end face, means supporting said abutment element from the valve plate in a position between the ends of said balancing cylinder but circumferentially clear of its walls, a sealing ring interposed between said abutment element and the balancing cylinder, to divide the balancing cylinder into a pressurized end space and a low pressure end space, a cylindrical skirt formed on said sealing ring and bearing liquid-tightly against the wall of the balancing cylinder, an annular seating on said sealing ring bearing substantially liquid-tightly against the transverse end face of the abutment element about an interior circle which is slightly less in area than the cross-section of the pressurized end space within the balancing cylinder and about an exterior circle at least as large in area as the same cross-section, the hydraulic pressure over the small area defined by such difference in area constituting the force urging the sealing ring against the abutment element.

2. A hydraulic assembly as defined in claim 1, wherein the cylindrical skirt integral with the sealing ring is sufficiently flexible to be urged by the pressure within such cylinder tightly against that wall.

3. A hydraulic assembly as in claim 1, including a leakage path to a low pressure region about the abutment element, externally of the annular seating of the sealing ring, to produce a pressure differential across the seating.

4. A hydraulic assembly as defined in claim 1, wherein the balancing cylinder is enlarged to a slightly larger diameter in the region of the sealing ring's annular seating, and said seating is of a width at its bearing surface ranging from its interior circle of somewhat less area than the cross section of the balancing cylinder, to an exterior circle of somewhat greater area than such cross section, and extends into the enlargement of the balancing cylinder.

5. A hydraulic assembly as in claim 1, and a filter located in the flow path between the pressure port in the the valve plate and the balancing cylinder.

6. A hydraulic assembly as in claim 1, and a magnet disposed in the flow path intermediate the pressure port in the valve plate and the balancing cylinder, in position such that all liquid flowing to such cylinder must pass in close proximity to the magnet, for filtering out of entrained particles.

7. In combination with a rotative cylinder block having a transverse end face, a non-rotative valve plate whereon said end face bears, two ports in said valve plate, one for intake and the other for discharge, a balancing recess in said cylinder block extending axially and closed at its end nearer the valve plate, an abutment element within and disposed transversely across the balancing recess, means supporting said abutment element from the valve plate in a position circumferentially clear of the walls of the balancing recess, and a sealing ring located within the balancing recess and bearing at two sealing surfaces upon said abutment element and the cylinder block, respectively, to divide the balancing recess into two chambers, a first at its closed end nearer the valve plate and a second distant therefrom, a first flow path connecting the first chamber with the high pressure port of the two ports and a second flow path connecting the second chamber with a low pressure region, whereby hydraulic reaction in the first chamber between the abutment element and the closed end of the balancing recess which is nearer the valve plate urges the abutting end faces of the cylinder block and valve plate together, one of the adjoining walls of the abutment element and the balancing recess having a cylindrical surface, a cylindrical seating formed on the sealing ring and constituting one of its sealing surfaces, bearing substantially liquid-tightly against said cylindrical surface, whereby the cylinder block and the abutment element are afforded relative axial movement, and an annular seating also formed on the sealing ring and constituting the second of its sealing surfaces, bearing substantially liquid-tightly against a seat at an end face of that one of the abutment element and the balancing recess other than the one which has said cylindrical bearing surface, whereby the cylinder block and the abutment element are afforded relative transverse movement by reason of the circumferential clearance between the abutment and the recess walls, said end-face bearing being about an interior circle of somewhat less area than the cross-sectional area of the cylindrical seating, the hydraulic pressure over the small area defined by such difference in area constituting the force to urge the annular seating against its seat.

8. In combination with a rotative cylinder block, an axially located balancing recess therein, a non-rotative valve plate whereon the end face of the cylinder block bears, intake and discharge ports formed in said valve plate, an abutment element supported from the valve plate and disposed transversely across the balancing recess intermediate its ends, with complete circumferential clearance, the balancing recess being closed at its end which is adjacent the valve plate, one at least of the adjacent surfaces of the abutment element and the recess being a cylindrical surface, and a sealing ring operatively disposed in sealing contact at two sealing surfaces respectively with said abutment element and said cylinder block, within the balancing recess, to divide said recess into a low pressure end distant from the valve plate having a flow path to a low pressure region and a pressurized end nearer the valve plate having a flow path connecting with the higher pressure port of the two ports, hydraulic reaction within which pressurized end between the abutment element and the recess end nearer the valve plate urges the end face of the cylinder block against the abutting end face of the valve plate, the sealing ring being formed

with a cylindrical seating cooperating substantially liquid-tightly as one of its sealing surfaces between the sealing ring and said cylindrical surface, but arranged to permit relative axial movement of the abutment element and the cylinder block, and being also formed with an annular seating bearing substantially liquid-tightly as the other of its sealing surfaces between said sealing ring and an end face of that member other than the one which has said cylindrical surface, and affording transverse movement between the abutment and the recess by reason of the circumferential clearance, said end-face bearing being about an interior circle of somewhat less area than the cross-sectional area of the cylindrical seating, whereby the hydraulic pressure over the small area defined by such difference in area constitutes the force to urge the sealing ring against its annular seating.

9. In combination with a rotative cylinder block having a transverse end face, a non-rotative valve plate which abuts such end face, intake and discharge ports in said valve plate, a balancing cylinder disposed axially within the cylinder block and enlarged in cross-section at its end distant from the valve plate, a flow path between the higher pressure port of the two ports and the smaller end of the balancing cylinder, the balancing cylinder being closed at its smaller end and having a leakage port to low pressure at its larger end, an abutment element disposed transversely across and with complete circumferential clearance relative to the enlarged end of the balancing cylinder, a sealing means cooperating between said abutment element and the balancing cylinder and separating the pressurized smaller end of the balancing cylinder and

the adjacent pressurized portion of its larger end from the leakage port, whereby hydraulic reaction between the abutment element and the closed smaller end of the balancing cylinder urges the end face of the cylinder block against the abutting face of the valve plate, said sealing means comprising a sealing ring within the balancing cylinder operatively interposed between said abutment element and the pressurized space, and sealing ring having two sealing surfaces, one whereof bears liquid-tightly against the wall of said balancing cylinder, and the other sealing surface whereof is formed with an annular sealing bearing substantially liquid-tightly against an end face of the abutment element about an interior circle of somewhat less area than the cross-sectional area of the pressurized smaller end, the hydraulic pressure over the small area defined by such difference in area constituting the force to urge the sealing ring against the abutment element.

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