Jan. 29, 1963 E. H. BOWERS ETAL 3,075,778

HIGH PRESSURE HYDRAULIC PUMPS OR MOTORS

Filed Feb. 25, 1959 3 Sheets-Sheet 1

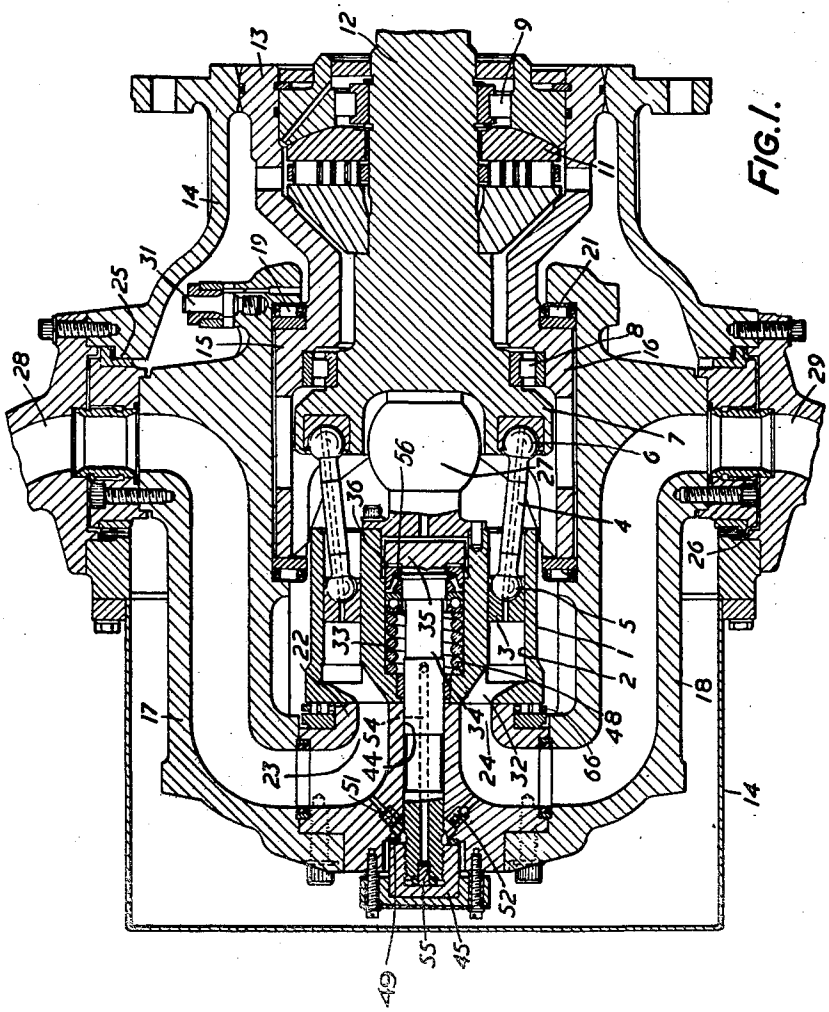

FIG. 1.

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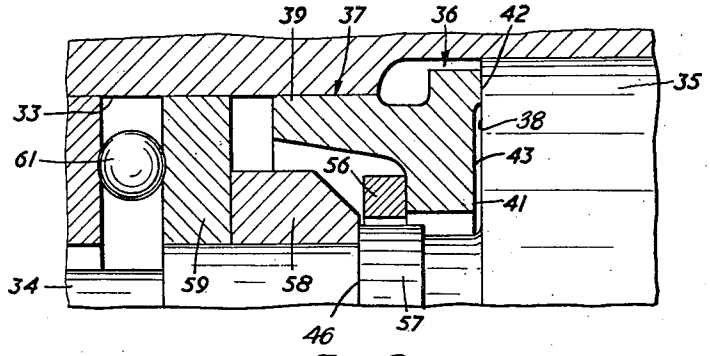

FIG. 2.

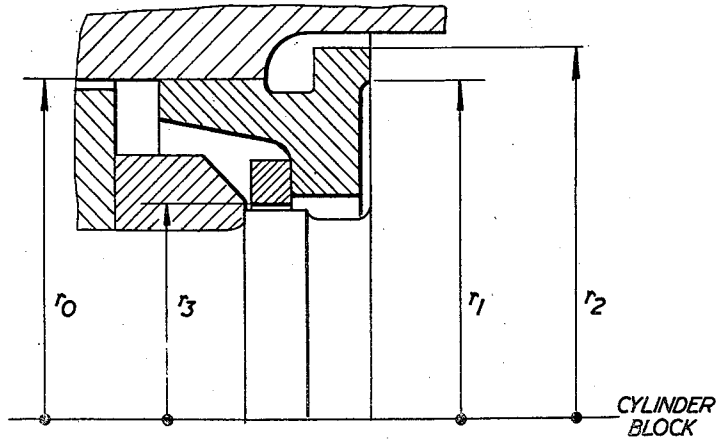

FIG. 3.

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HIGH PRESSURE HYDRAULIC PUMPS OR MOTORS

Filed Feb. 25, 1959 3 Sheets-Sheet 3

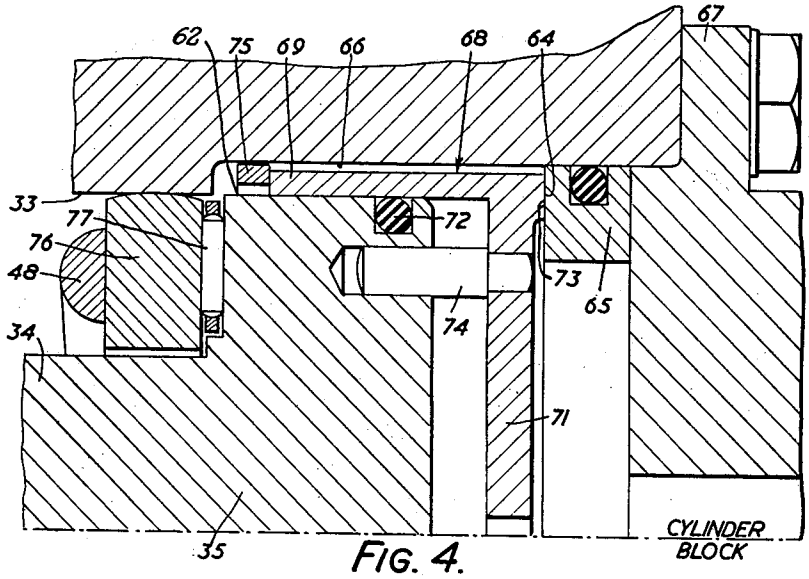

FIG. 4.

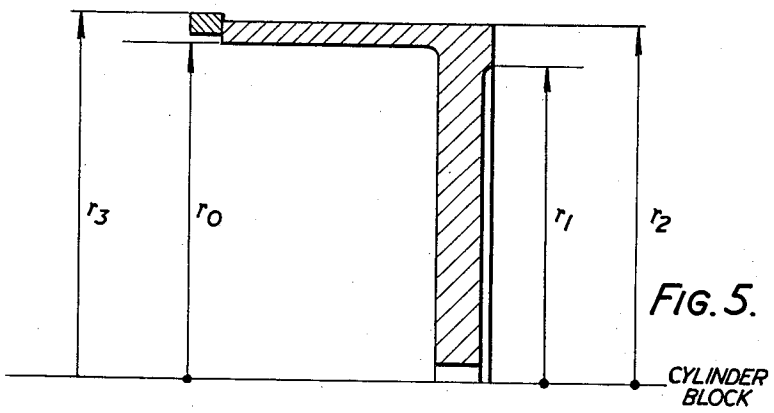

FIG. 5.

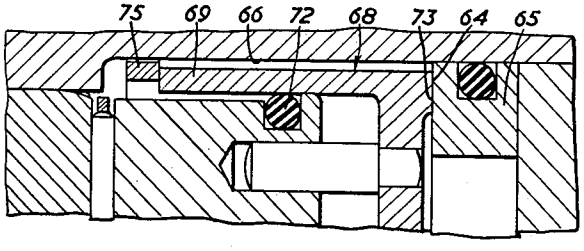

FIG. 6.

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United States Patent Office 3,075,778 Patented Jan. 29, 1963

3,075,778
HIGH PRESSURE HYDRAULIC PUMPS OR MOTORS

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Filed Feb. 25, 1959, Ser. No. 795,496
Claims priority, application Great Britain Feb. 26, 1958
12 Claims. (Cl. 277—3)

This invention relates to an improvement or modification in our prior patent application Serial No. 657,684, filed May 7, 1957, and is concerned with high pressure hydraulic pumps or motors of the kind comprising a rotating cylinder block having displacement cylinders regularly spaced about and located parallel or approximately parallel to the rotation axis, a valve plate on which the cylinder block rotates, and an axially disposed hydraulically balancing means acting between the cylinder block and the valve plate urging them together to counteract the hydraulic separating force acting between the valve plate and block. In this kind of pump or motor the balancing means is usually fed with pressure liquid from the pressure port in the valve plate and in order to obtain high efficiency it is desirable that leakage of pressure liquid from the hydraulic balancing means should be reduced to a minimum.

The object of this invention is to provide in a pump or motor of the kind referred to a hydraulic balancing means which permits of relative rotation between the valve plate and cylinder block without substantial leakage by the provision of a simple sealing arrangement which is reliable in operation and is automatically adjustable for the wear that may take place throughout the working life of the pump or motor.

A pump or motor of the kind referred to (as that term will be used in the claims) includes, as the balancing means referred to above, a central axially disposed recess or chamber within the rotative cylinder block. An abutment within the recess is fixed to a support that extends from the non-rotative valve plate with which the cylinder block cooperates. This abutment divides the recess, transversely of the rotative axis, into a high pressure zone nearer to the valve plate, and a low pressure zone remote from the valve plate. Pressure fluid from the high pressure port in the valve plate enters the high pressure zone, thereby urging the cylinder block against the valve plate. Means are provided for sealing, by means of a sealing ring bearing radially against a cylindrical seating and axially against an annular seating, one of which seatings is a surface of the recess and the other a surface of the abutment, against loss of pressure fluid from the high pressure zone to the low pressure zone, at least, in material amounts. The sealing arrangement is such, as explained more fully in the application Serial No. 657,684, that the areas of the sealing ring over which pressures act by virtue of the seatings are such as to cause a small but normally adequate axial force to be generated to hold the sealing ring in sealing engagement with the annular seating. A flow passage for relief to a low pressure region from the low pressure zone of the recess is normally provided, to accommodate such slight leakage as may occur past the annular seating.

In such a pump or motor of the kind referred to there is provided, by the present invention, a restricted flow passage in the high pressure zone which is in series with the possible leakage flow past the annular seating, such that if substantial leakage occurs past the annular seating a pressure drop occurs at the restricted flow passage. This causes an increase in hydraulic axial force exerted on the sealing ring, acting to push the sealing ring with increased axial force more tightly against the annular seating, thereby to reduce the leakage past the same.

In order that the invention may be clearly understood two examples of the invention will now be described with reference to the accompanying drawings, in which:

FIGURE 1 is a cross-section through a pump of the kind referred to and including a balancing means in accordance with the invention;

FIGURES 2 and 3 are detailed cross-sections to an enlarged scale of the balancing means used in FIGURE 1;

FIGURES 4 and 5 are detailed cross-sections of an alternative balancing means usable in the pump shown in FIGURE 1; and

FIGURE 6 is a modification of the construction in FIGURES 4 and 5.

The pump comprises basically a rotating cylinder block 1 having a plurality of displacement cylinders 2 lying parallel to the axis of block rotation and 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. 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 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 hinge 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 is diagrammatically shown at 27, this being in practice, of a constant velocity type, and it interconnects the thrust plate and the cylinder block to ensure that they rotate together. 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 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 axially disposed balancing recess 33 of cylindrical form 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 head 35. The head 35, although it divides the cylinder 33 into high and low pressure zones at left and at right, respectively, is located in an enlargement 36 at an end of the cylinder 33. A circular sealing ring 37 is located at the end of the cylinder 33 and bears, for example, against the flat undersurface 38 of the head 35. The undersurface 38, where the ring 37 contacts it, forms an annular seating at 42. The seal 37 includes a thin-walled cylindrical wall portion 39 which is a close fit within the cylinder 33 to constitute a cylindrical seating. The wall 39 is integral with a reinforcing flange 41, at the outer edge whereof the annular seating surface 42 is located. The inner edge of the annular seating surface 42 is arranged to have radius r_1 (see FIGURE 3) which is slightly smaller than effective radius r_0 of the cylinder 33 whilst the outer edge of the annular seating surface 42 extends into the recess 36 and is of a slightly larger radius r_2 as compared to the radius r_0. The reinforcing flange 41 is relieved at 43 on the surface adjacent to the surface 38 and inwardly of the annular seating 42.

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 from which an axial thrust bearing 61 reacts. 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 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 to retain any particles of a ferrous nature in the liquid flowing to cylinder 33. The passages 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.

All the above is known structure, being described in the application Serial No. 657,684. The present invention cooperates with a pump or motor of the kind just described.

In order to form a restricted flow passage for liquid from the cylinder 33 that may escape over seating 42 there is provided interiorly of the sealing ring 37 a throttle ring 56 whose interior diameter fits with a very slight clearance on an enlargement 57 of stem 34; see FIGURE 2. This ring has a small degree of axial movement limited on the one hand by contacting the flange 41 of the sealing ring and on the other hand by contacting a collar 58 which also performs the function of supporting a bearing member 59 of the ball race 61 from the shoulder 46.

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 be 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 on the side of abutment 35 nearer the valve plate to raise it to high pressure. This pressure will act on the cylindrical seating at 39 to urge it against the surface 33, and on the seal 37 to urge its seating 42 against the face 38 by virtue of the small difference in cross-sectional area between the wall portion 39 and the inner diameter of the seat 42. The enlargement 36 of the cylinder is in connection with low pressure by virtue of a small clearance existing between the end 35 of rod 32 and the enlargement 36 and the seat 42 is, therefore, positioned to seal between high and low pressure zones. A very small leakage is desirable in order than the seating 42 should not bear directly on the face 38. The fact that a minute flow of liquid leaks across the seating 42 means that a pressure gradient exists and a hydraulic force is exerted on the seat 42 which 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. The pressure acting on wall 39 will expand it slightly into liquid-tight engagement with cylinder 33 and at the same time cause a substantial friction grip to be exerted. Thus the seal will rotate with the block 1 and the seating 42 will rotate on the face 38.

In the event, during pump operation, that leakage flow over the seating 42 increases, an increased pressure drop will take place in the flow from the cylinder 33 between ring 56 and enlargement 57 to the seating 42. The effect of this increased pressure drop will be to reduce the pressure acting over the recessed portion 43 of the ring 37 thereby greatly increasing the axial hydraulic force acting on ring 37 to cause it to move more firmly into engagement with the seating 42. Such movement will reduce the leakage flow to a very small value at which the pressure drop in liquid flowing between ring 56 and enlargement 57 is very small. This very small pressure drop will, under normal operation, serve to hold the ring 56 against the interior surface of the flange 41 of the ring to prevent leakage between the ring 56 and the flange 41. When the pump is not operating and there is no pressure in the cylinder 33 the ring 37 may move slightly away from the seating 42 and on restarting of the pump an excessive leakage flow will take place initially before the throttle ring 56 is enabled to cause the ring 37 to seat on seating 42. This momentary excessive leakage possesses the advantage of flushing the seating 42 clear of any minute particles of solid matter that may have accumulated during the previous operation of the pump.

In normal operation of the sealing ring 37 there is a pressure gradient over seating 42 as the very small leakage flow takes place. If the low pressure zone, which exists in enlargement 36 and in the clearance between head 35 and enlargement 36 is a substantially zero pressure and the pressure gradient at seating 42 is uniform then for successful operation it is desirable for the cylinder radius r_0 to be approximately the arithmetic mean of the inner and outer radii r_1 and r_2 of the seating 42. r_0 may reasonably be less than this value if a slightly greater leakage is allowed, equilibrium being ensured by the pressure drop that occurs by virtue of throttle between ring 56 and enlargement 57 through which the leakage passes on its way to seating 42. This state of equilibrium is quite stable. The restricted flow passage could be

formed in many other ways than by ring 56, but a particular advantage in using ring 56 as shown is that in operation it can exert no side thrust between stem 34 and the cylinder block.

Reference is now made to FIGURES 4 and 5 where an alternative form of the balancing means is disclosed. The stem 34 as in the previous example extends axially along the cylindrical recess 33 in the cylinder block and the end of the stem is formed with a head 35. The spring 48 acts through a bearing member 76 and a roller race 77 on to the underside of the head 35, the other end of the spring acting against the base of the cylindrical recess 33. Here the similarity with the previous example ceases. The external surface 62 of the head 35 is formed as a cylinder co-axial with recess 33 and forms the cylindrical seating. The annular seating 64 is formed on a ring 65 securely fixed at the outer end of an enlargement 66 of recess 33. The mounting 67 for the universal joint 27 effectively closes the outer end of the enlargement 66 and prevents any axial movement of ring 65 as a result of force exerted on it. The sealing ring 68 comprises a thin-walled cylindrical portion 69 integrally formed with a circular disc-like end portion 71, the interior of the portion 69 being a good sliding fit on the cylindrical seating 62; a seal 72 around the cylindrical seating 62 prevents leakage of liquid over this seating. At the outer edge of the circular portion 71 an annular raised portion 73 is formed which alone engages the annular seating 64. A sliding pin 74 engages in both the head 35 and the circular portion 71 allowing axial movement of ring 68 on the cylindrical seating 62, but preventing rotational movement of the ring, the head 35 and stem 34 being non-rotative. At the inner end of the cylindrical portion 69 of the ring a throttle ring 75 is located which is slightly smaller in diameter than the enlargement 66 so that when the ring 75 engages the cylindrical portion 69 a restricted flow passage in series with liquid leaking over the annular seating 64 exists between the ring 75 and enlargement 66. A limited amount of axial movement only is available to the ring 75 by reason of its location near to the base of enlargement 66.

In normal operation, when the annular portion 73 of the sealing ring engages the annular seating 64 allowing a very slight flow of leakage liquid the arrangement of the ring is such that the hydraulic endwise force acting over the cross-sectional area of the cylindrical portion 69 is opposed by the hydraulic force due to the pressure gradient of leakage liquid over the annular seating 64. In the event that the ring 68 does not seal sufficiently effectively on the annular seating 64, an excessive leakage flow of liquid will take place which must pass between the ring 75 and the enlargement 66, involving a pressure drop which reduces the total force generated by the pressure gradient over the annular seating 64, and, at the same time, adds in effect to the cross-sectional area over which high pressure may act on the cylindrical portion 69 of the ring. The sealing ring 68 will thus be moved more forcibly against the annular seating 64 until the leakage flow is reduced to a sufficiently small value.

As mentioned with reference to FIGURES 2 and 3 it is desirable, if the pressure gradient over seating 64 is uniform and the pressure in the low pressure zone is substantially zero, for the radius r_0 of the cylindrical seating to be the arithmetic mean of the inner and outer radii of the annular seating 64. r_0 may be greater than this value if a slightly greater leakage is allowed, the pressure drop occurring at the restricted passage between ring 75 and enlargement 66 then ensuring stable equilibrium of the sealing ring.

Referring now to FIGURE 6, a modification of FIGURES 4 and 5 is shown in that the head 35 to the left of seal 72 is slightly reduced from the radius r_0 of the sealing ring. The purpose is to ensure that the cylindrical seating of the sealing ring does not restrain the sealing ring 68 against slight angular movement about transverse axes to allow the raised portion 73 to engage the annular seating 64 fully in spite of slight inaccuracies in the machining of these parts.

We claim as our invention:

1. In combination, a pair of members mounted for relative rotation, one of said members having a walled recess therein and the other of said members having an abutment portion thereof disposed coaxially in the recess and dividing it into two chambers communicating with one another between the relatively rotating surfaces of the abutment portion and the wall of the recess, an annular sealing element arranged in the recess coaxially adjacent the abutment portion and having one end face thereof opening into one of the chambers, and means operatively feeding high pressure fluid into said one chamber to apply axial force on said one end face of the annular sealing element, said annular sealing element having a cylindrical seating along one periphery thereof and the other end face thereof recessed to form an annular seating thereon, said cylindrical seating having a radius about the axis of the sealing element intermediate the inner and outer radii of said annular seating and being in fluid tight engagement with a corresponding seating defined by one of said abutment portion and said recess wall, said annular seating being so operatively spaced from a corresponding seating defined by the other of said abutment portion and said recess wall as to form a narrow clearance for small leakage flow between the two chambers, and said sealing element defining an axially-extending restricted flow passage between the end faces thereof communicating with the clearance to regulate leakage flow therethrough by responsively varying the pressure drop across the sealing element and therefore the pressure gradient in the clearance balancing said axial force.

2. In combination, a pair of members mounted for relative rotation, one of said members having a walled recess therein and the other of said members having an abutment portion thereof disposed coaxially in the recess and dividing it into two chambers communicating with one another between the relatively rotating surfaces of the abutment portion and the wall of the recess, an annular sealing element arranged in the recess coaxially adjacent the abutment portion and having one end face thereof opening into one of the chambers, and means operatively feeding high pressure fluid into said one chamber to apply axial force on said one end face of the annular sealing element, said annular sealing element having a cylindrical seating along one periphery thereof and the other end face thereof recessed to form an annular seating thereon, said cylindrical seating having a radius about the axis of the sealing element intermediate the inner and outer radii of said annular seating and being in fluid tight engagement with a corresponding seating defined by one of said abutment portion and said recess wall, said annular seating being so operatively spaced from a corresponding seating defined by the other of said abutment portion and said recess wall as to form a narrow clearance for small leakage flow between the two chambers, and the other periphery of the sealing element being so spaced from said other of the abutment portion and the recess wall as to define therebetween an axially-extending restricted flow passage communicating with the clearance to regulate leakage flow therethrough by responsively varying the pressure drop across the sealing element and therefore the pressure gradient in the clearance balancing said axial force.

3. The combination according to claim 2 wherein the annular sealing element includes a pair of rings disposed in coaxial end to end relationship.

4. The combination according to claim 2 wherein the annular sealing element includes a pair of coaxially disposed rings one of which has a greater outside diameter than the other and defines said restricted flow passage with the recess wall.

5. The combination according to claim 2 wherein the

annular sealing element includes a pair of coaxially disposed rings one of which has a smaller inside diameter than the other and defines said restricted flow passage with the abutment portion.

6. The combination according to claim 2 wherein the radius of the cylindrical seating is the arithmetic mean of the inner and outer radii of said annular seating.

7. In combination, a pair of members mounted for relative rotation, one of said members having a walled recess therein and the other of said members having an abutment portion thereof disposed coaxially in the recess and dividing it into two chambers communicating with one another between the relatively rotating surfaces of the abutment portion and the wall of the recess, an annular sealing element arranged in the recess coaxially adjacent the abutment portion and having one end face thereof opening into one of the chambers, means operatively feeding high pressure fluid into said one chamber to apply axial force on said one end face of the annular sealing element, said annular sealing element having a cylindrical seating along one periphery thereof and the other end face thereof recessed to form an annular seating thereon, said cylindrical seating having a radius about the axis of the sealing element intermediate the inner and outer radii of said annular seating and being in fluid tight engagement with a corresponding seating defined by one of said abutment portion and said recess wall, said annular seating being so operatively spaced from a corresponding seating defined by the other of said abutment portion and said recess wall as to form a narrow clearance for small leakage flow between the two chambers, the other periphery of the sealing element being so spaced from said other of the abutment portion and the recess wall as to define therebetween an axially-extending flow passage communicating with said clearance, and throttle means adjacent the flow passage to restrict flow therethrough and thereby regulate leakage flow through the clearance by responsively varying the pressure drop across the sealing element and therefore the pressure gradient in the clearance balancing said axial force.

8. The combination according to claim 7 wherein said throttle means includes a throttle ring disposed adjacent said other periphery of the sealing element in coaxial end to end relation therewith.

9. The combination according to claim 8 wherein said throttle ring is disposed adjacent said one end face of the sealing element.

10. In a variable displacement pump mechanism, a cylinder block having an axially extending walled recess therein, a valve plate mounted adjacent one end of the cylinder block, means for causing relative rotation between the plate and the block, said valve plate having an abutment thereon extending coaxially within the recess and dividing it into two chambers communicating with one another between the relatively rotating surfaces of the abutment and the wall of the recess, an annular sealing element arranged in the recess coaxially adjacent the abutment and having one end face thereof opening into one of the chambers, and means operatively feeding high pressure fluid into said one chamber to apply axial force on said one end face of the annular sealing element, said sealing element having a cylindrical seating along one periphery thereof and the other end face thereof recessed to form an annular seating thereon, said cylindrical seating having a radius about the axis of the sealing element intermediate the inner and outer radii of said annular seating and being in fluid tight engagement with a corresponding seating defined by one of said abutment and said recess wall, said annular seating being so operatively spaced from a corresponding seating defined by the other of said abutment and said recess wall as to form a narrow clearance for small leakage flow between the two chambers, and said sealing element defining an axially-extending restricted flow passage between the end faces thereof communicating with the clearance to regulate leakage flow therethrough by responsively varying the pressure drop across the sealing element and therefore the pressure gradient in the clearance balancing said axial force.

11. In a variable displacement pump mechanism, a cylinder block having an axially extending walled recess therein, a valve plate mounted adjacent one end of the cylinder block, means for causing relative rotation between the plate and the block, said valve plate having an abutment thereon extending coaxially within the recess and dividing it into two chambers communicating with one another between the relatively rotating surfaces of the abutment and the wall of the recess, an annular sealing element arranged in one of the chambers coaxially adjacent the abutment and having one end face thereof fronting into said one chamber, means on the valve plate operatively feeding high pressure fluid into said one chamber to apply axial force on said one end face of the annular sealing element, said annular sealing element having a cylindrical seating along the outer periphery thereof and the other end face thereof recessed to form an annular seating thereon, said cylindrical seating having a radius about the axis of the sealing element intermediate the inner and outer radii of said annular seating and being in fluid tight engagement with a corresponding seating defined by the recess wall, said annular seating being so operatively spaced from a corresponding seating defined by the abutment as to form a narrow clearance for small leakage flow between the two chambers, the inner periphery of the sealing element being so spaced from the abutment as to define therebetween an axially-extending flow passage communicating with said clearance, and a throttle ring disposed in said one chamber adjacent the flow passage and in coaxial end to end relation with said one end face of the sealing element to restrict flow through the passage and thereby regulate leakage flow through the clearance by responsively varying the pressure drop across the sealing element and therefore the pressure gradient in the clearance balancing said axial force.

12. In a variable displacement pump mechanism, a cylinder block having an axially extending walled recess therein, a valve plate mounted adjacent one end of the cylinder block, means for causing relative rotation between the plate and the block, said valve plate having an abutment thereon extending coaxially within the recess and dividing it into two chambers communicating with one another between the relatively rotating surfaces of the abutment and the wall of the recess, an annular sealing element arranged in the recess between said surfaces coaxially adjacent the abutment and having one end face thereof opening into one of said chambers, means on the valve plate operatively feeding high pressure fluid into said one chamber to apply axial force on said one end face of the annular sealing element, said annular sealing element having a cylindrical seating along the inner periphery thereof and the other end face thereof recessed to form an annular seating thereon, said cylindrical seating having a radius about the axis of the sealing element intermediate the inner and outer radii of said annular seating and being in fluid tight engagement with a corresponding seating defined by that one of said surfaces on the abutment, said annular seating being so operatively spaced from a corresponding seating defined by the recess wall of the other of said chambers as to form a narrow clearance for small leakage flow between the two chambers, the outer periphery of the sealing element being so spaced from that one of said surfaces on the recess wall as to define therebetween an axially-extending flow passage communicating with said clearance, and a throttle ring disposed in said one chamber adjacent the flow passage and in coaxial end to end relation with said one end face of the sealing element to restrict flow through the passage and thereby regulate leakage flow through the clearance by responsively varying the pressure drop across the sealing element and therefore the

pressure gradient in the clearance balancing said axial force.

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