United States Patent [19]

Dixon

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[54] **RADIAL HYDRAULIC MOTORS AND PUMPS**

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July 28, 1969 Australia 58,627/69

[52] **U.S. Cl.** **91/488**

[51] **Int. Cl.** **F01b 13/06**

[58] **Field of Search** 91/486, 487, 481; 92/119

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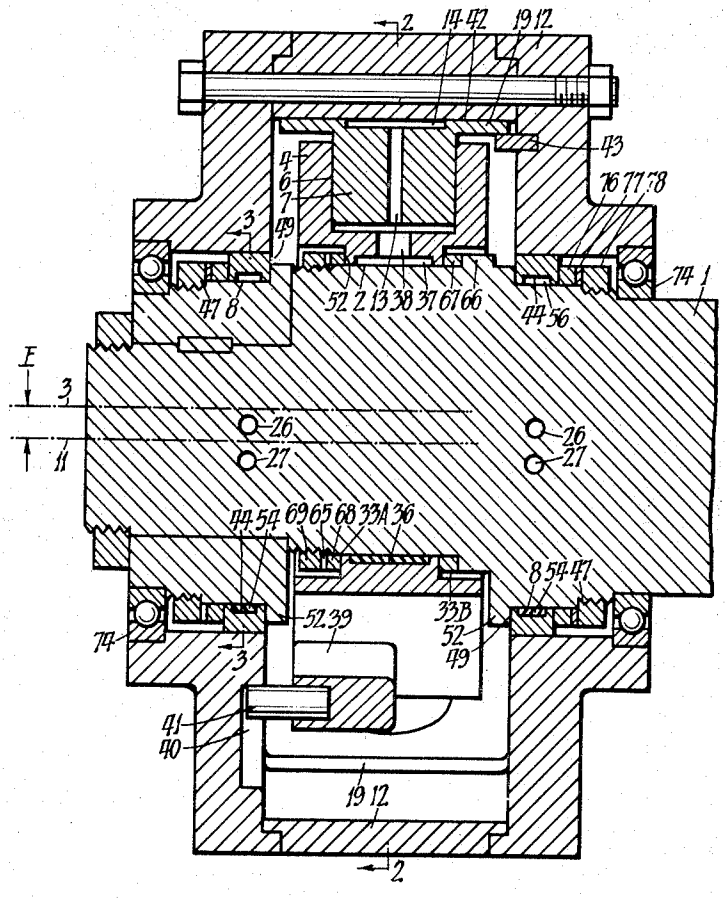
Primary Examiner—William L. Freeh

Attorney—Oberlin, Maky, Donnelly & Renner

[57] **ABSTRACT**

The invention provides an improvement of a radial hydraulic motor or pump of the type having a cylinder block rotatable about a first axis, pistons in the cylinders which have radially inward working faces, and a rotor rotatable about a second axis spaced from and parallel to the first axis; the radially outward ends of the pistons slidably bearing on chordal flats on the rotor. The improvement comprises replacing the pistons by reciprocating members which may be in or on the cylinders and which have a port passing through them so that radial outward forces occasioned by hydraulic fluid in the cylinders are borne hydraulically substantially entirely and substantially directly by the flats on the rotor rather than by the working faces of the pistons and, in turn, mechanically by the flats on the rotor.

6 Claims, 18 Drawing Figures



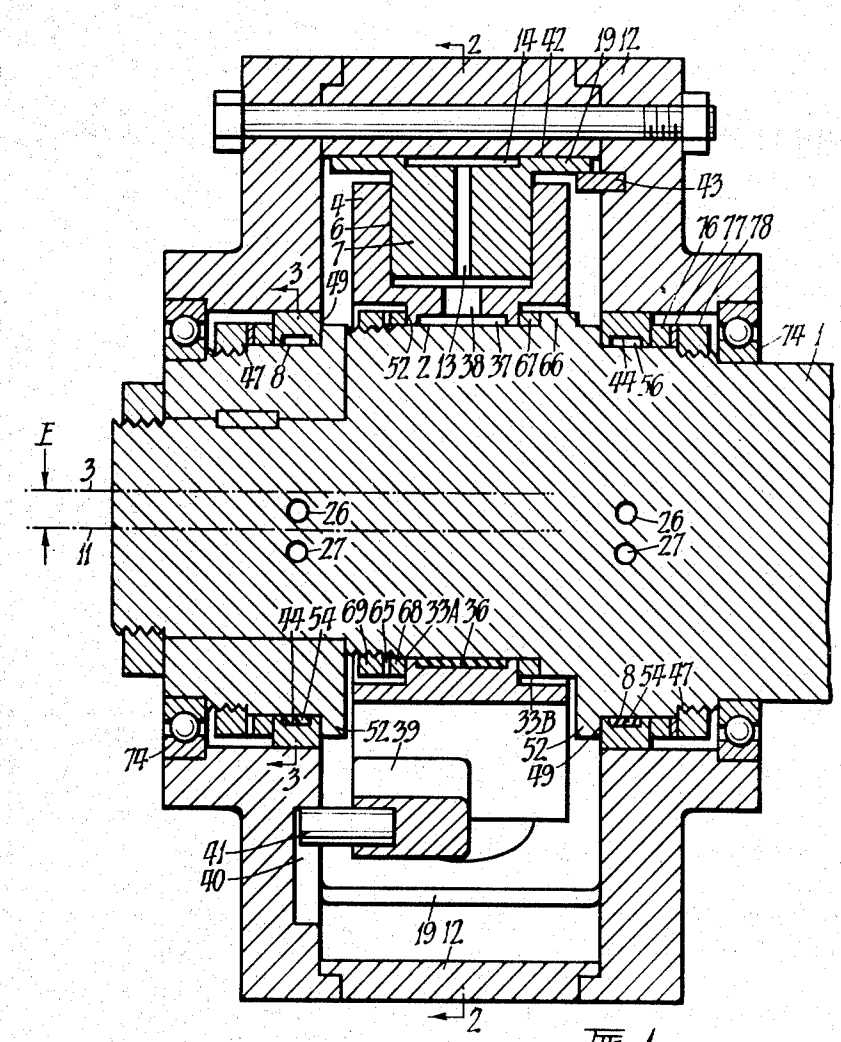

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Fig. 1

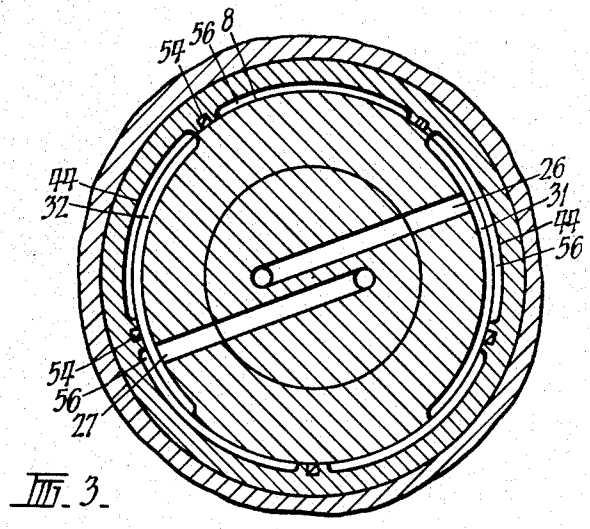

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Fig. 3

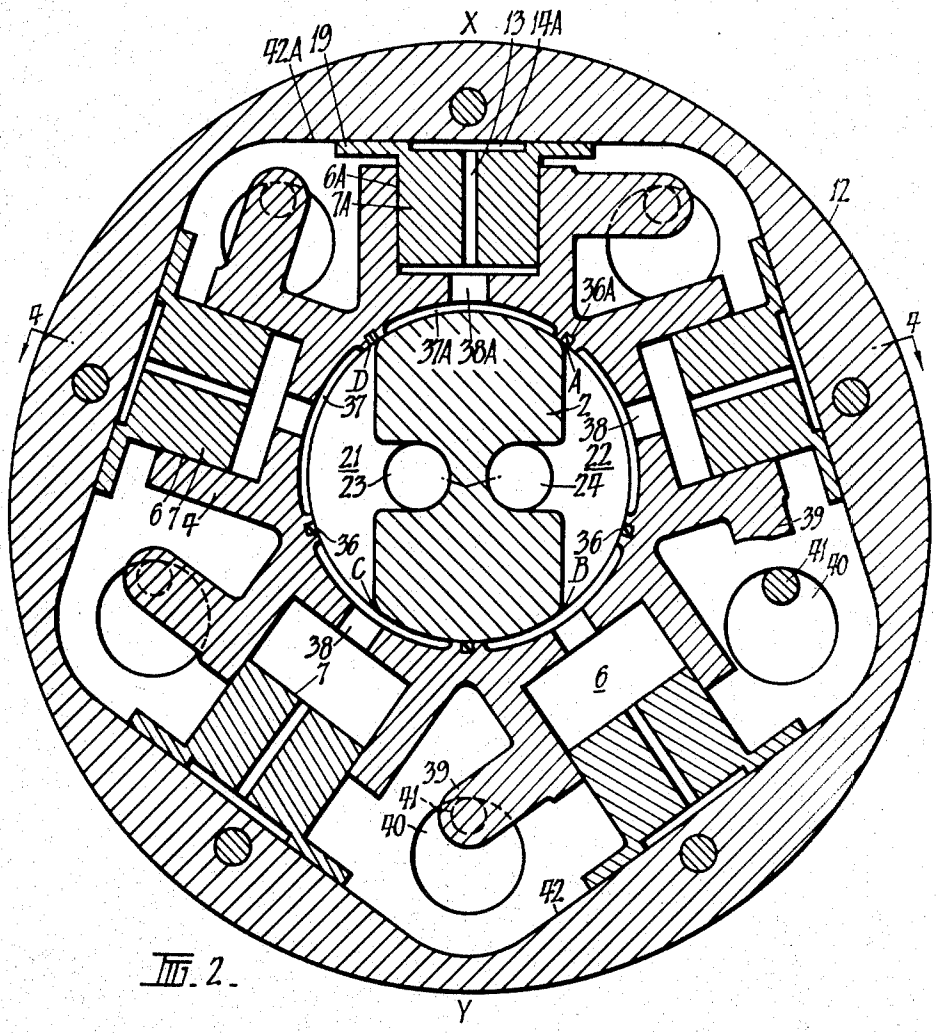

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FIG. 2.

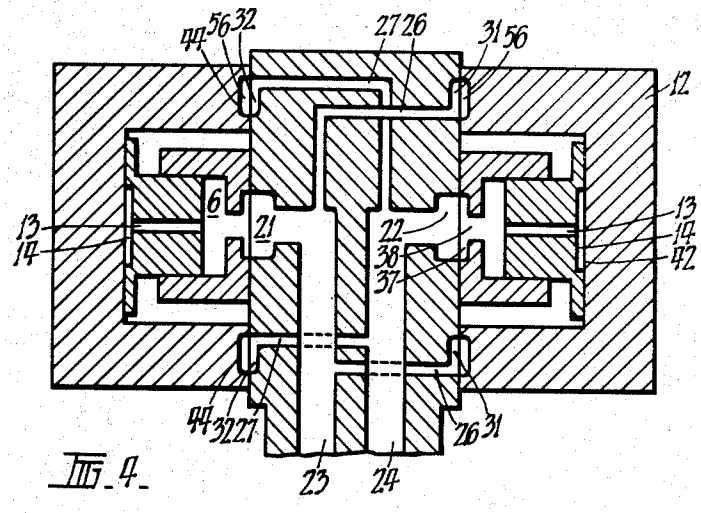

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FIG. 4.

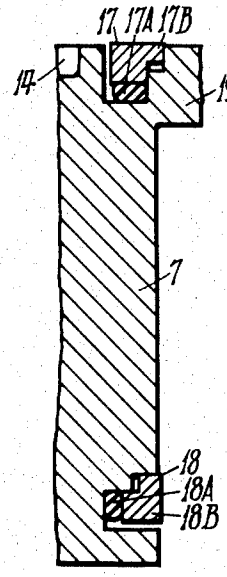


FIG. 5

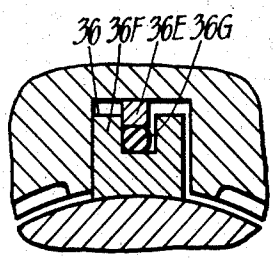


FIG. 6

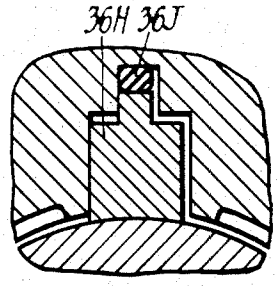


FIG. 7

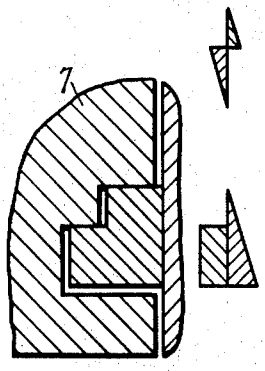


FIG. 8A

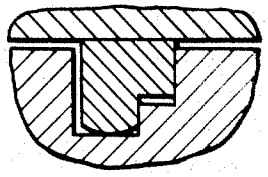


FIG. 8B

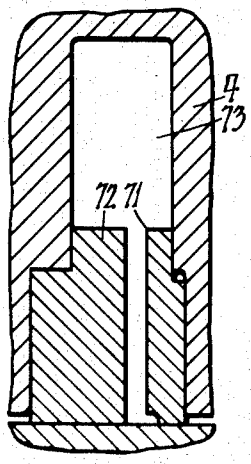


FIG. 9A

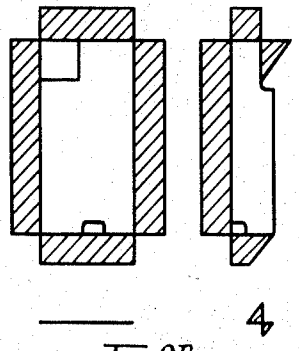


FIG. 9B

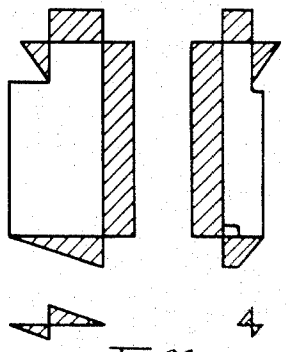


FIG. 9C

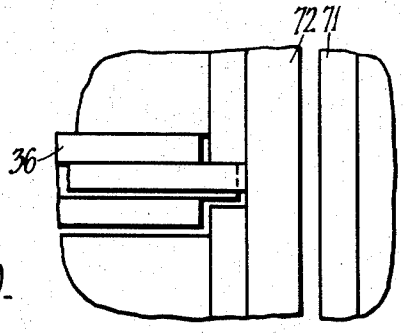


FIG. 10

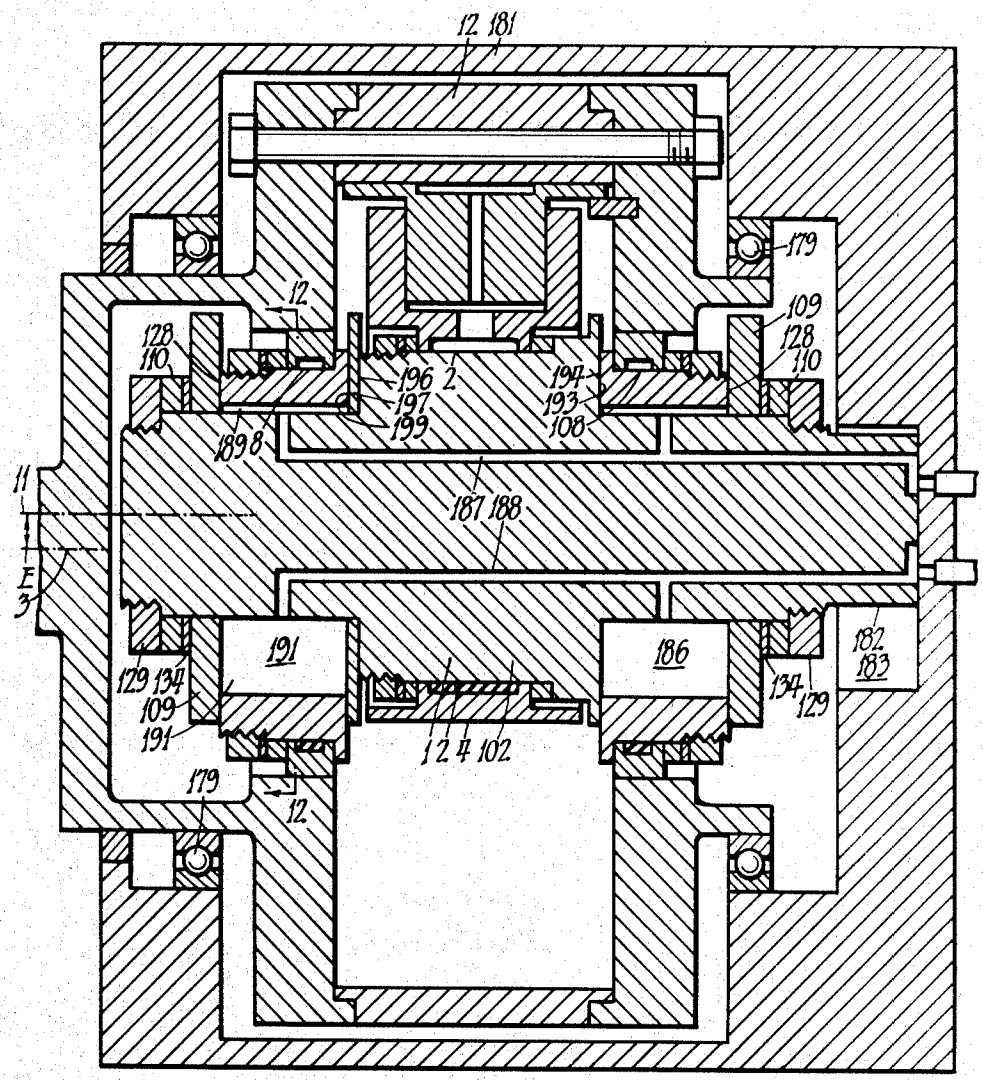

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FIG. 11

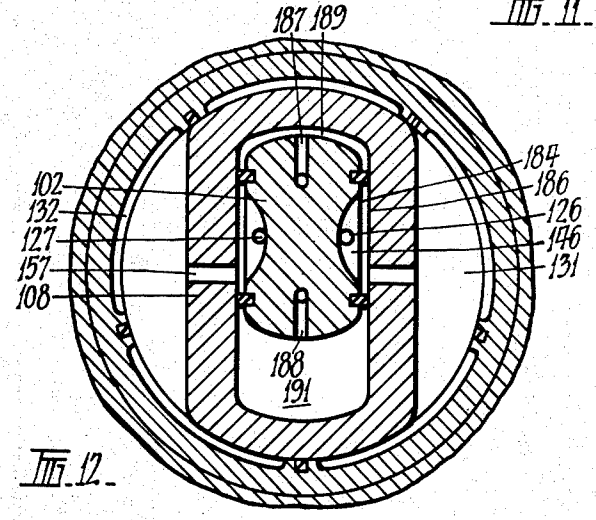

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FIG. 12

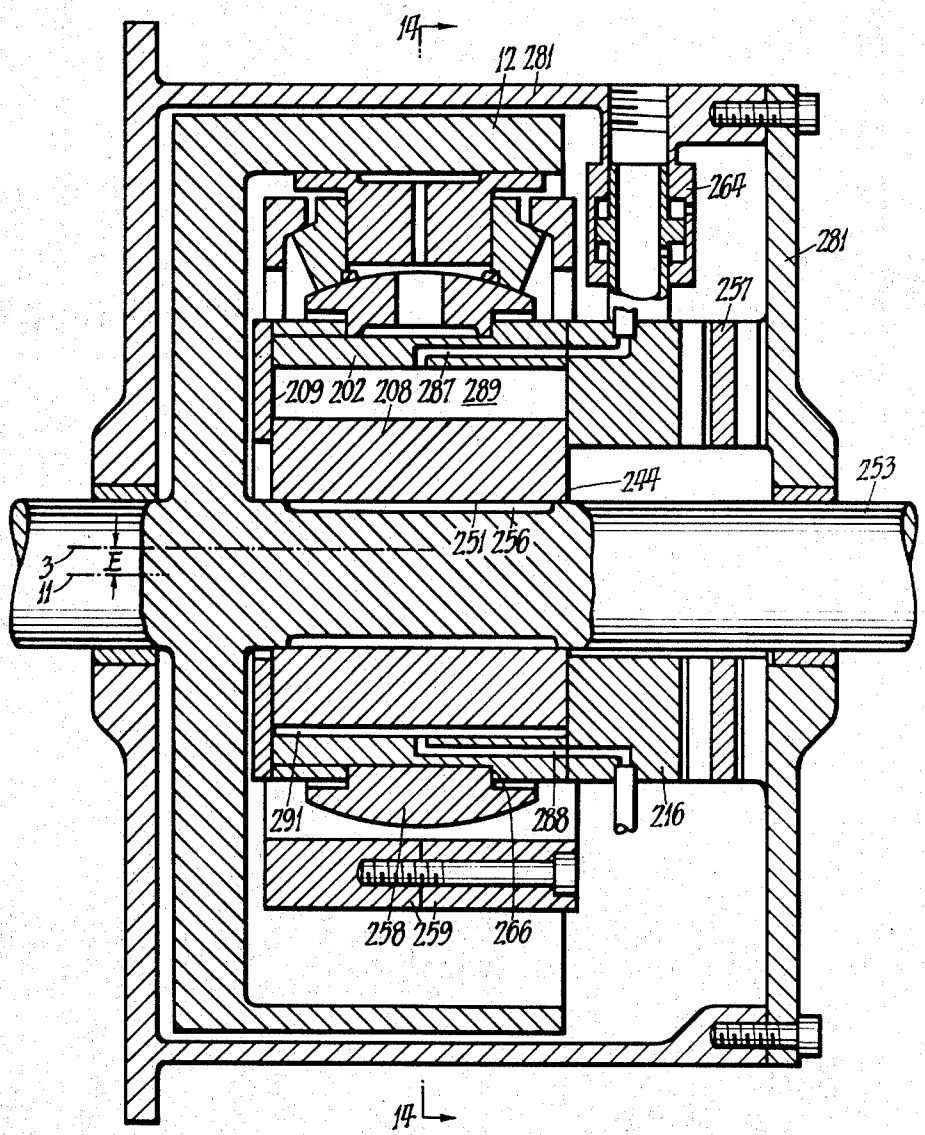

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FIG. 13

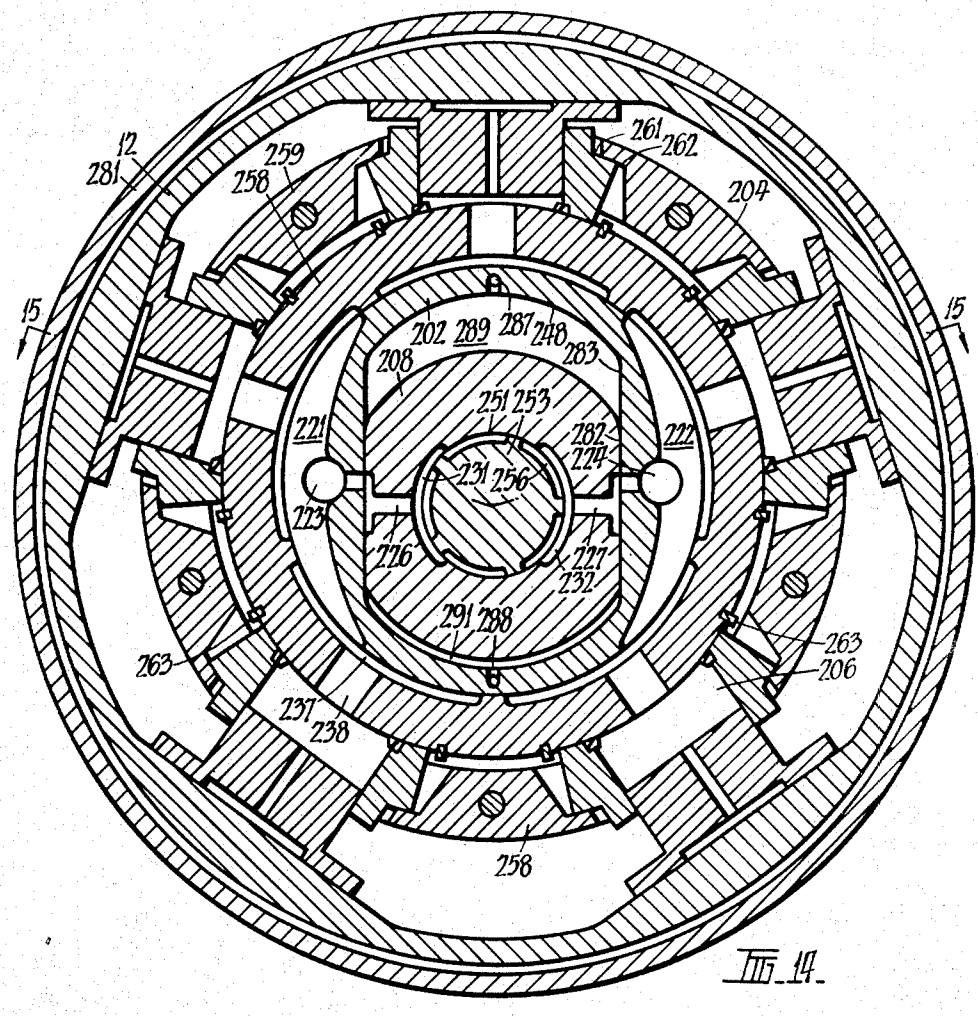

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Fig. 14

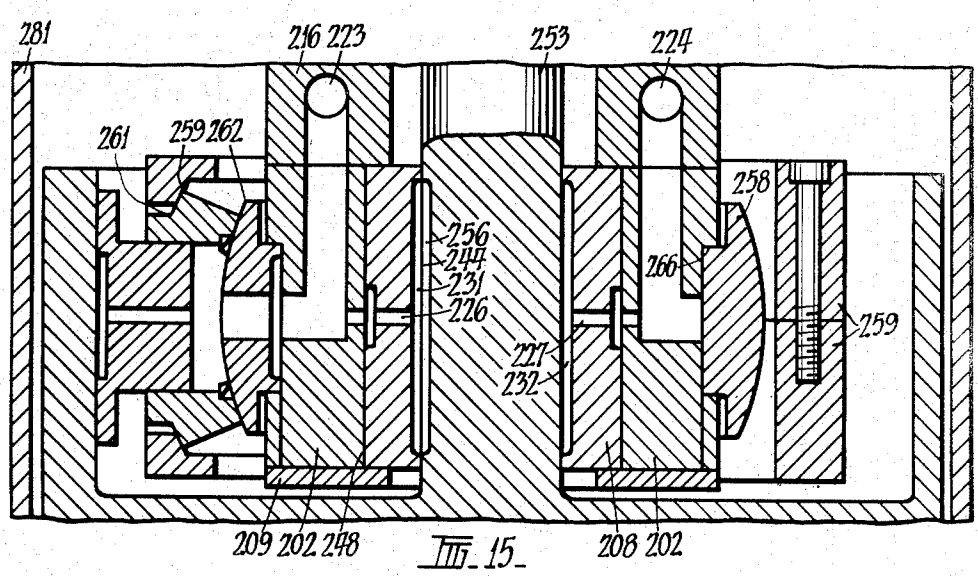

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Fig. 15

RADIAL HYDRAULIC MOTORS AND PUMPS

FIELD OF INVENTION

This invention relates to radial hydraulic motors or pumps.

BACKGROUND OF INVENTION

Radial hydraulic motors or pumps are known which comprise a cylinder block rotatable about a first axis, pistons in the cylinders which have radially inward working faces, and a rotor rotatable about a second axis parallel to and spaced from the first axis and having chordal flats on which the radially outward ends of the pistons slidably bear.

Theoretically, forces acting on or through the pistons are all radial to the first axis and pass through the central axes of the cylinders and pistons and thus there should not be any turning moment on the pistons about said central axes. In practice, however, it is found that unless parts are machined to close tolerance and/or the pistons and cylinders have substantial overlap even in the maximum cylinder volume condition there is a tendency for turning moments to act on the pistons and thus cause jamming.

Since it is undesirable to have to machine to close tolerances and since it is generally desirable to have the diameter of the motor or pump as small as possible, the above solutions to the jamming problem are not always practicable.

Accordingly, I have studied such motors or pumps with a view to providing an at least partial solution to the problem of jamming.

My approach has been that the pistons can, essentially, be substantially omitted insofar as their function of receiving force from, and transmitting force to, hydraulic fluid is concerned and that it is possible to use the rotor as an equivalent of piston working faces.

In describing the present invention it is necessary to have an understanding of the points of similarity of pumps and motors and the general manner of operation thereof. To facilitate this I explain that work is performed in the case of a motor when hydraulic fluid under pressure is admitted to cylinders and in the case of a pump when hydraulic fluid under pressure is driven out of cylinders. This work is performed during working strokes and it is to be particularly understood that the working stroke of a motor is during induction and that of a pump is during exhaust. Conversely, the non-working stroke of a motor is during exhaust and that of a pump is during induction. Fluid which is adapted to do work in the case of a motor and on which work has been done in the case of a pump is conveniently known as work fluid whereas that which is exhausted in the case of a motor and inducted in the case of a pump is conveniently known as non-work fluid.

BRIEF SUMMARY OF INVENTION

According to the present invention there is provided a radial hydraulic motor or pump comprising a cylinder block relatively rotatable about a first axis, reciprocating members in the cylinders, and a rotor relatively rotatable about a second axis parallel to and spaced from the first axis, and having chordal internal faces on which the radially outward ends of the reciprocating members slidably and sealingly bear. First fliud port means are provided which extend through the reciprocating members to put said faces in fluid communication with said cylinders substantially at work fluid pressure and over areas whereby radial outward forces occasioned by hydraulic fluid in said cylinders during working strokes are borne hydraulically at least substantially entirely and substantially directly by said faces. Second fluid port means are provided operative to put fluid into communication with said rotor substantially at work fluid pressure and over areas whereby to exert, in use, a substantially equal and generally opposite force thereon to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders during at least a substantial part of working strokes, and wherein the effective working area of the cylinder block acted upon radially inwardly and radially outwardly by work fluid during work strokes is substantially the same.

As a result of said faces bearing said forces hydralically and at least substantially entirely and directly the forces acting on the reciprocating members, as compared to the pistons of the prior art, are at least substantially reduced and thus the tendency to jamming is reduced as compared to the prior art. From this it is possible to make motors or pumps with parts that are not machined to close tolerance and with relatively small diameters for given capacity.

Preferably the radially outward ends of the reciprocating members carry seal means adapted to sealingly engage with said faces to restrict against the loss of hydraulic fluid from the cylinders.

In a preferred construction the motor or pump comprises a bearing member having a first cylindrical portion on the first axis and a second cylindrical portion on the second axis; the cylinder block relatively rotating, in use, with respect to the first portion and the rotor relatively rotating, in use, with respect to the second portion. In this construction the second port means preferably comprises porting in the bearing member in communication, in use, with work fluid and opening to the circumference of the second portion whereby work fluid exerts on the rotor a substantially equal and generally opposite force to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders duuring at least a substantial part of working strokes. In a particularly preferred form the second port means comprises two sets of portings in the bearing member opening diametrically oppositely to one another to the circumference of the second portion and in use communicating, respectively, with work or non-work fluid and non-work or work fluid whereby to enable operation both as pump or motor with either direction of relative rotation and in any such circumstance being adapted for one or the other of said portings to put work fluid in communication with the rotor whereby to exert thereon a substantially equal and generally opposite force to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders during at least substantial part of working strokes. In a particular form of the last the rotor is provided with recesses open to the circumference of the second portion having effective working areas such as, in use, to exert on the rotor, by co-operation with the opening of said second port means to the circumference of the second portion, a substantially equal and generally opposite force to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders during at least a substantial part of working strokes. Said recesses preferably extend annularly

angularly of the second portions such as to co-operate, in use, with the opening of said second port means to the circumference of the second portion as stated for at least a substantial part of working strokes.

Preferably means are provided for varying the spacing of said axes.

In a preferred form the motor or pump has a shaft having a cylindrical outer surface intermediate its ends, constituting said first cylindrical portion, and two cylindrical members, each having an outer cylindrical surface which surfaces, together, constitute said second cylindrical portion, non-rotatably mounted on said shaft at axially opposite ends to said first cylindrical portion; said shaft and said two cylindrical members being movable relative to one another in a direction diametric to said axes in an imaginary plane passing through said axes so as to alter the spacing of said axes. There may be a chamber, defined at least in part by said shaft and one of said two cylindrical members, into which fluid under pressure can be passed to cause a force to be exerted between said shaft and said one of said two cylindrical members to cause relative movement as stated. Most preferably there are two sets of chambers, defined at least in part by said shaft and said two cylindrical members, diametrically spaced in said plane and in that fluid duct means are provided whereby fluid under pressure may be passed into either of said sets to cause relative movement as stated.

In another preferred form the motor or pump has a first shaft having a cylindrical outer surface, constituting said first cylindrical portion, and a rotor mounting member, having a cylindrical bore which constitutes said second cylindrical portion and which contains a second shaft relatively rotatable therein and connected to the rotor, non-rotatably mounted at least in part within said first shaft; said first shaft and said rotor mounting member being movable relative to one another in a direction diametric of said axes in an imaginary plane passing through said axes so as to alter the spacing of said axes. There may be a chamber, defined at least in part by said first shaft and said rotor mounting member, into which fluid under pressure can be passed to cause a force to be exerted between said first shaft and said rotor mounting member to cause relative movement as stated. Most preferably there are two chambers, defined at least in part by said first shaft and said rotor mounting member, diametrically spaced in said plane and in that fluid duct means are provided whereby fluid under pressure may be passed into either of said chambers to cause relative movement as stated.

DESCRIPTION OF DRAWINGS

To aid in the further understanding of this invention a number of devices in accordance therewith and modifications will now be described with the aid of the accompanying drawings in which:

FIG. 1 is a cross-sectional view of a device in accordance with this invention;

FIG. 2 is a sectional view on line 2—2 in FIG. 1;

FIG. 3 is a sectional view on line 3—3 in FIG. 1;

FIG. 4 is a cross-sectional view along line 4—4 in FIG. 2 and showing parts schematically;

FIG. 5 is a sectional view of a part of the device;

FIG. 6 is a sectional view of another part of the device;

FIG. 7 is a sectional view showing an alternative part to that shown in FIG. 6;

FIG. 8A is a sectional view illustrating an alternative part to one part shown in FIG. 5 and also shows pressure gradients and resultants and FIG. 8B is a sectional view illustrating an alternative part to another part shown in FIG. 5;

FIG. 9A is a sectional view showing a further part of the device and in FIGS. 9B and 9C are shown pressure gradients and resultants;

FIG. 10 is a view showing a still further part of the device;

FIG. 11 is a cross-sectional view corresponding to FIG. 1 of a modified device;

FIG. 12 is a sectional view approximately on line 12—12 in FIG. 11;

FIG. 13 is a cross-sectional view corresponding to FIG. 1 of another modified device;

FIG. 14 is a sectional view on line 14—14 in FIG. 13; and

FIG. 15 is a sectional view approximately on line 15—15 in FIG. 14.

DETAILED DESCRIPTION

FIGS. 1–10

The device shown in FIGS. 1–4 is adapted for use as a motor or as a pump. The arrangement of its principal parts and its manner of operation will firstly be described and thereafter more specific details of certain parts, details of certain other parts and modifications will be given.

ARRANGEMENT OF PRINCIPAL PARTS

The device comprises a dead shaft 1 having a first cylindrical portion 2 having an axis 3. A cylinder block 4 is rotatable on the portion 2 and has five cylinders 6. In each cylinder 6 is a reciprocating member 7.

The shaft 1 also has further cylindrical portions 8 having an axis 11. A rotor 12 is rotatable about the axis 11 on portions 8 and it is to be noted that the axes 3 and 11 are parallel but spaced apart a distance E — the eccentricity.

Each of the reciprocating members 7 has a port 13 extending therethrough, recesses 14 on the radial outward ends which are bounded by seals, circumferential seals and shoulders 19. The effective areas of each of the recesses 14 is substantially the same as but slightly less than the effective working areas of cylinders 6.

The shaft 1 has two fluid chambers 21 and 22 which are in communication with, respectively, ports 23 and 24.

Further ports 26 and 27 in communication with, respectively, ports 23 and 24 open to, respectively, recesses 31 and 32 in the circumference of the further portions 8 diametrically opposite to, respectively, chambers 21 and 22.

The cylinder block 4 has peripheral seal means 33A and 33B and cross seals 36, recesses 37 and ports 38 putting the recesses into communication with the cylinders 6. The effective working areas of each of the areas defined by the peripheral seals means 33 and cross seals 36 (effectively, the effective working areas of each of the recesses 37) is substantially equal to the effective working area of the cylinders 6.

The cylinder block 4 also has arms 39 which carry followers 41. The ends of the followers are located in circular recesses 40 which have a diameter equal to twice E plus the diameter of the followers 41.

The rotor 12 has five chordal flats 42, abutments 43 which serve to engage under shoulders 19 on the reciprocating members 7 to keep the radially outward ends thereof in close sealing proximity to the flats 42.

The rotor 12 has bearing surfaces 44 which are rotatable on the further portions 8 of the dead shaft 1 and it will be realised that the chambers 31 and 32 open to those bearing surfaces. Peripheral seals constituted by seal means 47 and the abutment of sides 49 of the rotor 12 against shoulders 52 on the shaft 1 are provided and cross seals 54 are also provided.

The bearing surfaces 44 each have five recesses 56. The effective areas defined by adjacent cross seals 54 and the peripheral seals (effectively, the effective areas of each of the recesses 56), is, on each bearing surface, substantially equal to half the effective area of a cylindr 6 and thus it will be realised that similarly angularly disposed recesses 56 on the bearing surfaces have, together, an effective area substantially equal to that of a cylinder 6.

OPERATION AS A MOTOR

The operation of the above described device as a motor for rotation of the rotor 12 in a clockwise direction as viewed in FIG. 2. will now be described.

Hydraulic fluid under pressure (work fluid) is admitted to port 24 and passes into chamber 22.

Considering a cylinder, 6A, in approximately position X, if moved slightly clockwise therefrom, the cross-seal 36A no longer engages with the part of the shaft between A and D and as a result work fluid can pass from chamber 22 into recess 37A, through port 38A into cylinder 6A. Since the effective areas of recesses 37A and cylinder 6A are substantially the same there is substantially no radial outward or inward force exerted on the cylinder block.

In cylinder 6A work fluid passes through port 38A into recess 14A and it is to be noted that as the effective area of the recess 14A and cylinder 6A is substantially the same but that the former is slightly less than the latter, radial inward and outward forces on the radial inward and outward ends of the reciprocating member are substantially balanced but that there is a small force tending to keep the reciprocating member 7A in close sealing proximity with the flat 42A. It is also to be noted that the engagement of shoulders 19 with abutment 43 also serves to maintain the reciprocating members 7 in close sealing proximity with the flats 42.

In the recess 14A the work fluid acts upon the flat 42A and exerts an outward force radial to axis 3 and passing through the centre line of cylinder 6A.

Thus it will be realised that radial outward forces occasioned by hydraulic fluid in the cylinders 6 are borne hydraulically at least substantially entirely and directly by the flats 42 and this should be compared with the prior art where such forces are transmitted hydraulically directly to the piston and mechanically directly by the pistons to the flats.

The radial outward force acting on the flat 42A is radial to axis 3 but is off-centre with respect to axis 11 and hence there will be a turning moment acting on the rotor 12 tending to turn it clockwise with respect to the FIG. 2 view.

It is to be noted, however, that work fluid exerts no direct turning moment on the cylinder block 4 and that the force required to turn it is only that necessary to overcome friction. Because of the engagement of the reciprocating members 7 with the flats 42 the block 4 is constrained to turn with the rotor 12. Further, the engagement between the followers 41 and circular recesses 40 further acts to constrain the cylinder block 4 to turn with the rotor 12 and also serves to reduce the tendency to jam as a result of drive to the block 4 being not solely through the reciprocating members 7.

Thus the block 4 and rotor 12 turn with the same angular velocity and it will be realised that the cylinder 6A is undergoing a working stroke between X and Y and that when cross-seal 36D passes point B on portion 2 the working stroke is complete.

Continued movement of cylinder 6A past Y causes cross-seal 36A to be moved past point C on portion 2 and the cylinder 6A commences to undergo a non-working stroke in which fluid is exhausted via chamber 21 and port 23.

It is also to be noted that while fluid is acting on the flats 42 of the rotor 12 it is also acting on the bearing surfaces 44.

This arises in that ports 27 are in communication with port 24 (and ports 26 are in communication with port 23) and hence work fluid is admitted into recesses 32 and recess 56 where it acts on the bearing surfaces 44. As previously noted, the effective areas of each of the recesses 56 is half that of a cylinder 6 and thus there will be a net radial outward force acting on the bearing members which is generally oppositely directed and substantially equal to the radial outward forces acting on the flats 42. (It is particularly to be noted that the direction is not wholly opposite to those radial outward forces as, due to the eccentricity E the direction will be radial to the axis 11. This, however, is of little consequence.) Thus there will be a balancing.

To reverse the direction of rotation of rotor 12 it is merely necessary to connect work fluid to port 23 in which case the port 24 is for exhaust (non-work fluid).

In this case the recesses 31 receive work fluid and balancing as described above will result.

OPERATION AS A PUMP

In use as a pump the rotor 12 is rotated, say, clockwise with respect to FIG. 2 and fluid to be pumped is supplied, generally under a pressure slightly in excess of ambient, to port 24. A cylinder 6A moving between X and Y will draw non-work fluid thereinto in a non-working stroke and when moving between Y and X will pump work fluid out via port 23 in a working stroke.

It is to be particularly noted that radial outward forces occasioned by hydraulic fluid in the cylinders 6 during working strokes are borne hydraulically at least substantially entirely and directly by the flats 42 as compared to the prior art where those forces are borne hydraulically directly by the pistons which in turn transmit them mechanically directly to the flats.

In operation as a pump for rotation in the above stated direction, the recesses 31 receive work fluid and a balancing results as described with respect to use as a motor.

If the direction of rotation of rotor 12 is anti-clockwise with respect to FIG. 2 then non-work fluid will be inducted through port 23 and work fluid will be exhausted through port 24. In this case the recesses 32 receive work fluid and a balancing as described above results.

MORE SPECIFIC DETAILS OF CERTAIN PARTS AND DETAILS OF CERTAIN OTHER PARTS

Suitable seals (17) for bounding the recesses 14 and reciprocating member circumferential seals (18) are as shown in FIG. 5 and each comprises an O-ring 17A or 18A and an annulus 17B or 18B having an L-shaped radial-section. An alternative circumferential seal to seal 17 (without O-ring) is shown in FIg. 8A and pressure gradients and resultants are also shown in that Figure and an alternative to seal 17 (without O-ring) is shown in FIG. 8B.

The cylinder block cross-seals 36 may be as shown in FIG. 6 and in this case each comprises an annulus 36E having a square radial-section, an O-ring 36F and an annulus 36G having a U-shaped radial-section. FIG. 7 shows an alternative comprising annulus 36H and O-ring 36J and both FIGS. 6 and 7 also show the condition with work fluid to the right and non-work fluid to the left.

The cylinder block peripheral seal means 33A and 33B may be as shown in FIG. 1. The seal 33B shown is constituted by annular shoulder 66 and annulus 67 against which the cylinder block 4 bears. The seal 33A may be similar but an adjustable arrangement which comprises an annulus 68 and an annulus 69 which is screw-threaded to the shaft 1 and which serves the same function as annular shoulder 66. Plastic metal 65 is inserted into a gap between 68 and 69 during assembly and the annulus 69 is screwed on to the shaft 1 to bring the annulus 68 to bear against the cylinder block 4. The use of plastic metal obviates the need for machining to close tolerances.

An alternative cylinder block peripheral seal is shown in FIG. 9A and comprises annuli 71 and 72 located in a groove 73 in the cylinder block 4. The mating of one of those peripheral seals with a cross-seals 36 is shown in FIG. 10.

Pressure gradients of those peripheral seals and resultants are shown in FIGS. 9B and 9C.

Roller bearings 74 may also be provided to take external loads.

Cross seals 54 in the bearing surfaces 44 are preferably constructed similarly to those shown in FIG. 6, and peripheral sealing results from the engagement of sides 49 of the rotor 12 with shoulders 52 on the shaft 1 and peripheral seal means 47 which comprise annuli 76 plastic metal 77 and screw threaded annuli 78 similarly as described above with respect to the cylinder block peripheral seals shown in FIG. 2.

MODIFICATIONS

In the modifications hereinafter described attention is to be paid to reference numerals used. Where one or two figure numerals are identical to those used in FIGs 1–10 the relevant part is substantially the same. Where three figure numerals are used and the last two figures correspond to numerals used in FIGS. 1–10, and/or, in the case of FIGS. 13–15, correspond to the last two figures used in FIGS. 11 and 12 reference numerals, the parts so referenced are constructionally different but operatively similar.

FIGS. 11 AND 12

The modification shown in FIGS. 11 and 12 is constructed and operates similarly to the device shown in FIGS. 1–4.

The principal difference is the provision for altering the eccentricity E which comprises the rotor 12 being rotatable about axis 11 by means of bearings 179 in housing 181 and providing means for altering the relative disposition of axis 3, the axis about which the cylinder block 4 rotates, to axis 11; i.e., the eccentricity E.

The means for altering the relative disposition of the axes comprises the shaft 1 being in parts, 102 and 108 the part 102 comprising the cylindrical portion 2 and the parts 108 comprising the cylindrical portions 8.

The shaft part 102 has parallel sides at 182 and is slidable in a guideway 183 of similar shape in housing 181. The shaft part 102 also has parallel sides, at 184, and is slidable in guideways 186 of similar shape in parts 108. As a result of the engagement of the parallel sides at 182 and 184 in guideways 183 and 186 the shaft part 102 can be moved vertically with respect to FIG. 11; i.e., the axis 3 can be moved vertically but it is to be noted that the axis 11 is non-movable. As a result of this the eccentricity is alterable. Mechanical linkage means may be used to adjust and maintain the relative dispositions of the axes but the preferred means comprises ducts 187 and 188 opening into chambers 189 and 191. By passing hydraulic fluid under pressure into chambers 189 or chambers 191 the eccentricity may be altered.

Seal means for the chambers 189 and 191 comprise the abutment of side 193 of shaft part 108 and the side 194 of shaft part 102, the abutment of side 196 of shaft part 102 with plate 197 which in turn abuts with the side 199 of the cylinder block and plates 109 bearing at one side on sides 128 of shaft parts 108 and borne against on the other sides by annuli 110 and threaded — annuli 129 with plastic metal 134 being inserted between annuli 110 and plates 109.

As a result of the provision for altering eccentricity it is necessary to provide means whereby ports 26 and 27 are constantly in communication with chambers 131 and 132. This is acheived as shown in FIG. 12 by providing recesses 146 in shaft part 102 each of which is in communication with one of ports 157 in shaft part 108 for all relative dispositions of axes 3 and 11.

The construction shown in FIGS. 11 and 12 is operable as a variable capacity motor or pump and the rotor is provided with a shaft which, in the former case, acts as an output shaft and, in the latter case, as an input shaft.

FIGS 13–15

The modification shown in FIGS. 13–15 is constructed and operates similarly to the device shown in FIGS. 1–10.

The following major points of difference are, however, to be noted:

The form of the shaft 1 and the arrangement of the cylindrical portions 2 and 8,

The provision of means for altering eccentricity,

The location of means operative to cause the exertion of a substantially equal and generally opposite force to the radial outward forces acting on the flats during working strokes, and

The manner of construction of the cylinder block.

In the construction shown in FIGS. 13–15 the shaft 1 is comprised of a first, outer, cylindrical part 202 on axis 3 the outer circumference of which is operatively equivalent to cylindrical portion 2 and second, inner, part 208 having a cylindrical bore 151 on axis 11 there-

through the circumference of which being operatively equivalent to cylindrical portions **8.**

The rotor has a shaft **253** which rotates within bore **251** and the circumference **244** of that shaft is operatively equivalent to bearing surfaces **44.**

Bore **248** through part **202** has parallel surfaces which constitutes guideway **283** and part **208** has similar parallel surfaces **282** whereby part **202** is made vertically slidable with respect to FIG. **14.** Thus the relative dispositions of axes **3** and **11** and hence the eccentricity E is alterable. As in the construction shown in FIGS. **11** and **12** mechanical linkages may be provided for altering and maintaining a desired relative disposition of axes. however, once again the preferred means is the use of hydraulic fluid under pressure which can be forced via port **287** or **288** into chambers **289** or **291.**

The location of the means operative to cause the exertion of a substantially equal and generally opposite force to the radial outward forces acting on the flats during working strokes is substantially different from that shown in FIGS. **1–4** or **11** and **12** but is mechanically equivalent.

In this instance the circumfrence **244** or shaft **253** has recesses **256** corresponding to recesses **56,** part **208** has recesses **231** and **232** corresponding to chambers **31** and **32,** and ports **226** and **227** communicate with ports **224** and **223,** respectively, via recesses **246** which ensure that that communication is maintained for all relative dispositions of axes **3** and **11.** The effective area of each of the recesses **256** is the same as that of a cylinder **6.** The operation of this means is equivalent to the corresponding means shown in FIGS. **1–4.**

Ports **223** and **224** are provided in part **202** and extend into sleeve **216** (which may be integral with part **202**) for fluid communication to chambers **221** and **222** and there are telescopic tubes **264** to enable fluid to flow to and from the chambers **221** and **222.**

An Oldham coupling **257** between sleeve **216** and housing **281** is provided to prevent part **202** from rotating.

The left hand (with respect to FIG. **13**) axial ends of chambers **289** and **291** are sealed by plate **209** which may be fixed to either of parts **202** and **208** and the right hand (with respect to FIG. **13**) axial ends of chambers **289** and **291** are sealed by sleeve **216** which may be fixed to part **202** or part **208** but which, having regard to the Oldham coupling **257,** is preferably fixed to part **202** or is integral therewith.

The cylinder block **204** is made of a number of parts being annulus **258,** cylinders **206** and two cylinder connecting rings **259.**

The annulus **258** has ports **238** therethrough corresponding to ports **38** and recesses **237** corresponding to recesses **37.** The effective areas of each of recesses **237** is equal to that of a cylinder **206** and this has the same effect as described with respect to FIGS. **1–4.**

The radially outer surface of annulus **258** is based on a sphere and the radially inner ends of the cylinders **206** are contoured to suit. The cylinders **206** have shoulders **261** having radially outer surfaces which are also based on a sphere and the connecting rings **259,** taken together, have seats **262** based on the same sphere. Bolt means are provided for securing the rings **259** together and thus to hold the cylinders **206** relative to one another. Abutments **263** are provided on the radially outer surface of annulus **258** to limit rotation of the cylinders and connecting rings on that surface.

This construction of cylinder block **204** is particularly advantageous from a manufacturing point of view.

Sealing between the cylinder block and part **202** is achieved by abutment of annulus **258** with shoulder **266** on part **202** and the abutment of annulus **258** with annulus **268.**

In this construction it is to be noted that as in FIGS. **1–4,** and **11** and **12** the effective area of recesses **14** in reciprocating members **7** is substantially the same but slightly less than that of a cylinder **206** and thus radial outward forces occasioned by hydraulic fluid in the cylinders during working strokes are borne hydraulically at least substantially entirely and substantially directly by the flats **42** on the rotor.

The above described constructions have axes **3** and **11** non-rotating and the cylinder blocks and rotors rotate thereabouts. It is to be noted, however, that this invention extends to relative rotation and thus constructions in which, referring, as an example, to the device shown in FIGS. **1–4,** the shaft rotates about axis **3** or about axis **11** are to be considered as being included.

These and other modifications may be made without departing from the spirit and scope of this invention which is defined by the appended claims.

I claim:

1. A radial hydraulic motor or pump comprising a cylinder block having a plurality of cylinders relatively rotatable about a first axis, reciprocating members in said cylinders, and a rotor relatively rotatable about a second axis parallel to and spaced from the first axis, and having chordal internal faces on which the radially outward ends of the reciprocating members slidably and sealingly bear; characterized in that each of said reciprocating members is formed with a recess in the radially outer end thereof substantially equal but slightly less in area than the area of the associated cylinder and each of said cylinders is formed with an elongated recess at the radially inner periphery thereof substantially equal in area to the area of the cylinder in which the reciprocating member is positioned, and said rotor is formed with a plurality of recesses in the radially inner periphery thereof, first fluid port means are provided which extend through the reciprocating members to put said faces in fluid communication with said cylinders substantially at work fluid pressure and over areas whereby radial outward forces occasioned by hydraulic fluid in said cylinders during working strokes are borne hydraulically at least substantially entirely and substantially directly by said faces, with said recesses at the radially inner periphery of each cylinder functioning to create a balance of radially inward and radially outward forces on said cylinder caused by said work fluid during the working strokes, and second fluid port means are provided operative to put fluid into communication with said recesses in said rotor substantially at work fluid pressure, said recesses in said rotor having areas and being located such that said work fluid exerts, in use, a substantially equal and generally opposite force on said rotor to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders during at least a substantial part of working strokes.

2. A motor or pump as claimed in claim **1** characterized in that said cylinder block is provided with at least three projections engaged in complemental apertures

formed in said block rotor whereby to constrain the cylinder block and rotor to rotate, in use, about their respective axes at the same angular velocity, said projections and apertures being of circular cross-section with the diameter of each of said apertures being equal to twice the spacing of the first and second axes plus the diameter of the respective projections.

3. The motor or pump as claimed in claim **1** characterized in that the motor or pump comprises a bearing member having a first cylindrical portion on the first axis and a second cylindrical portion on the second axis; the cylinder block relatively rotating, in use, with respect to the first portion and the rotor relatively rotating, in use, with respect to the second portion.

4. The motor or pump as claimed in claim **3** characterized in that said second port means comprises porting in the bearing member in communication with recesses formed in the outer circumference of the second portion, which recesses are in turn in fluid communication sequentially with said recesses formed in said rotor so that work fluid exerts on the rotor a substantially equal and generally opposite force to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders during at least a substantial part of working strokes.

5. The motor or pump as claimed in claim **4** characterized in that said second fluid port means comprises two sets of portings in the bearing member opening diametrically oppositely to one another to the circumference of said second portion and communicating with said recesses formed in the rotor which are located axially on both sides of said cylinders whereby to enable operation both as pump or motor with either direction of relative rotation and in any such circumstance being adapted for one or the other of said portings to put work fluid in communication with the rotor so as to exert thereon a substantially equal and generally opposite force to the radial outward forces acting on said faces occasioned by hydraulic fluid in said cylinders during at least a substantial part of working strokes.

6. The motor or pump as claimed in claim **5** characterized in that said recesses formed in said rotor on each side of said cylinder are equal in number to said cylinders and are separated by sealed lands, with each of said recesses being substantially equal in area to approximately one-half the effective area of each recess formed in the radially outer end of said rotor, whereby a pair of said recesses in said rotor, when pressurized during the working strokes, exert a substantially equal and generally opposite force on said rotor to the radial outward forces acting on said faces thereby balancing said rotor.

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