

July 21, 1959

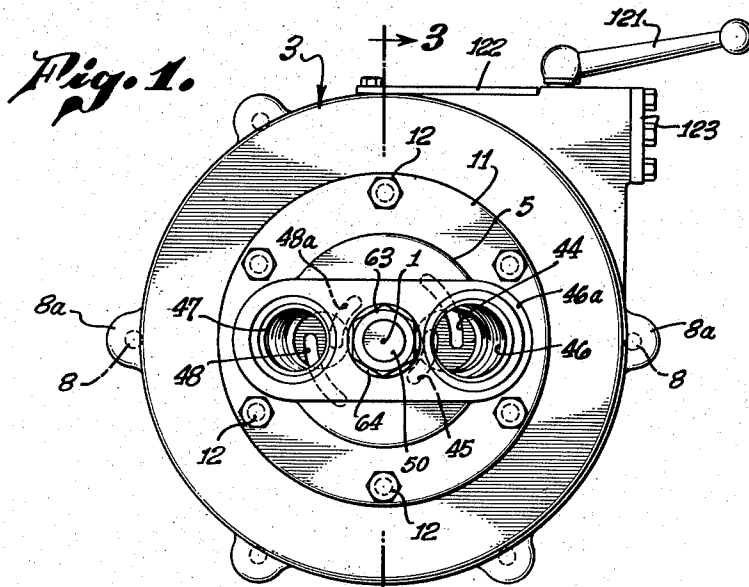
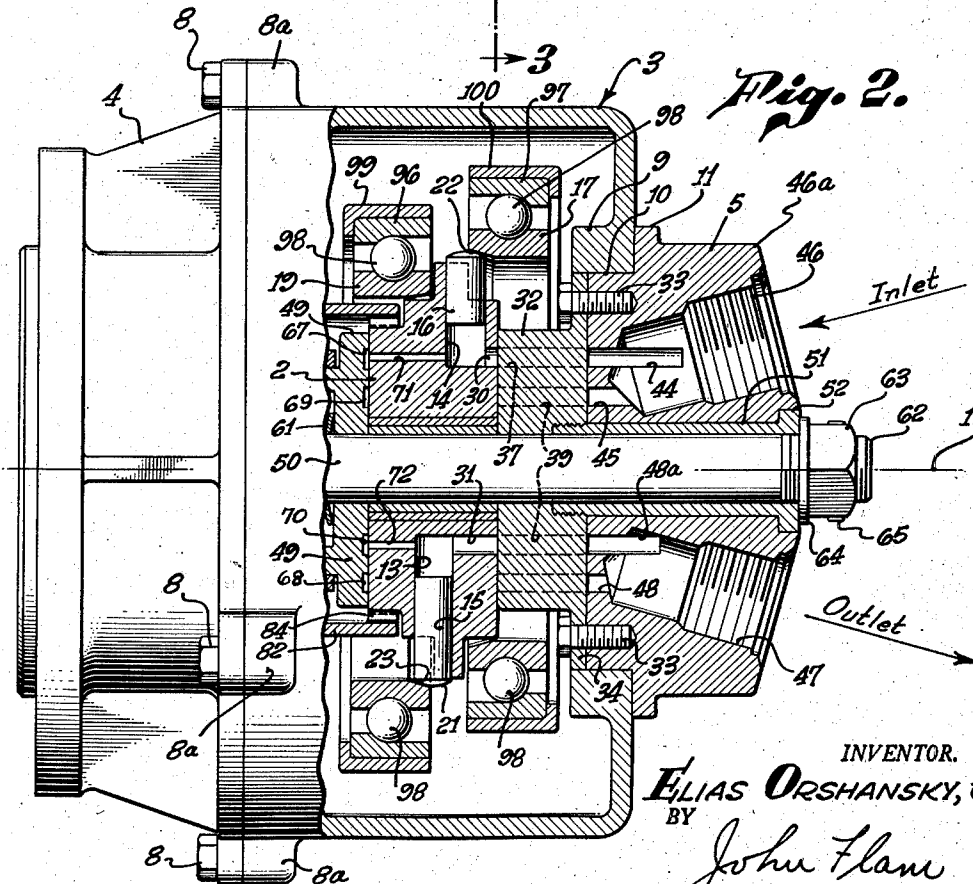
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2,895,426

HYDRAULIC APPARATUS UTILIZING ROTARY CYLINDER BLOCKS

Filed Dec. 27, 1952

4 Sheets-Sheet 1



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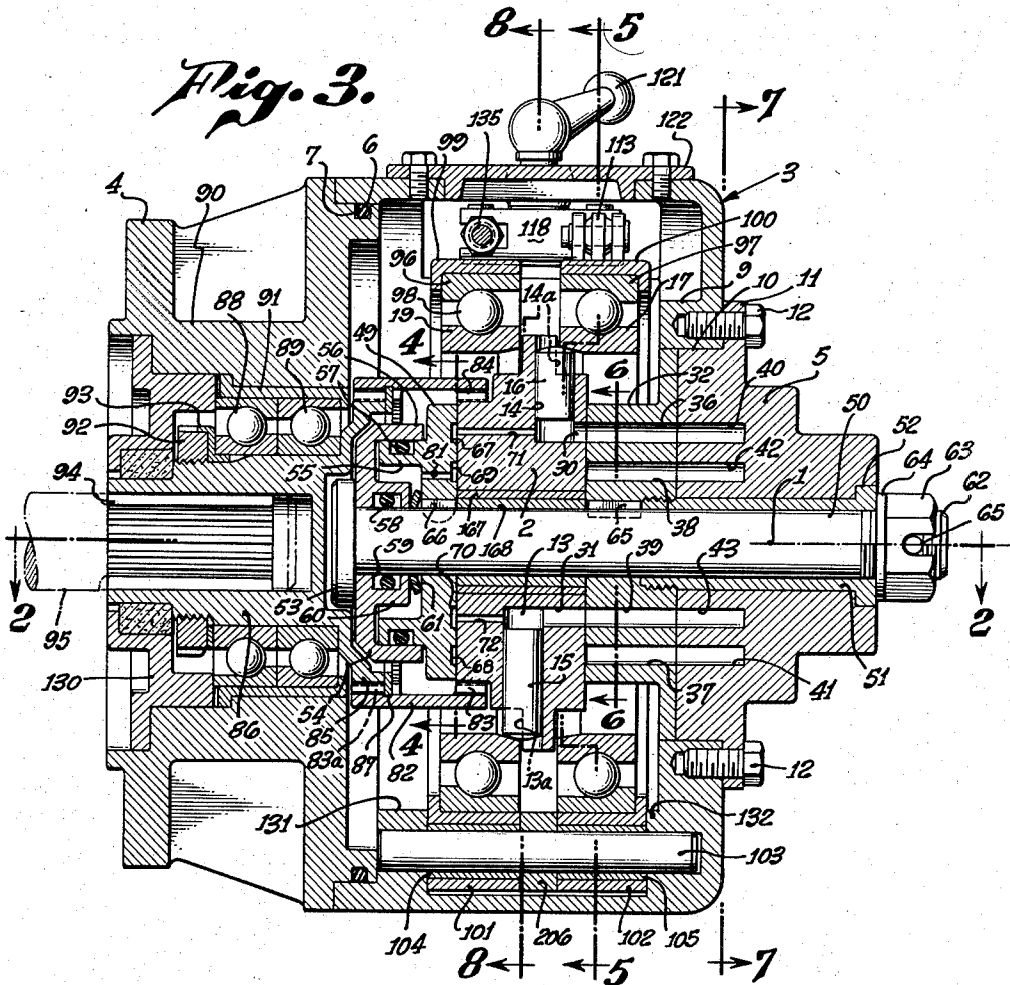
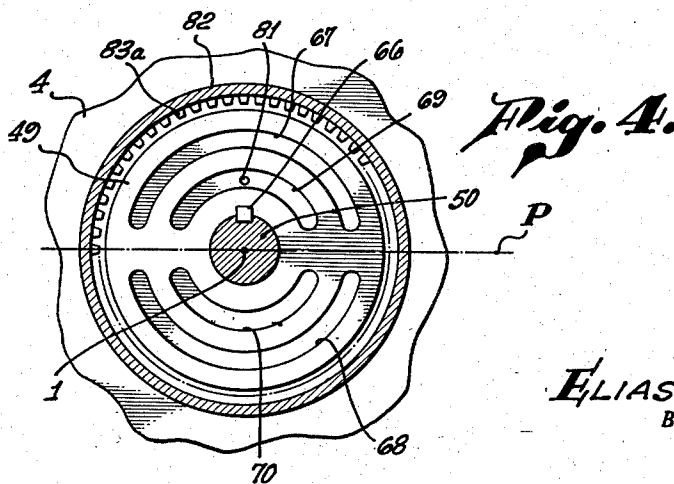
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4 Sheets-Sheet 2



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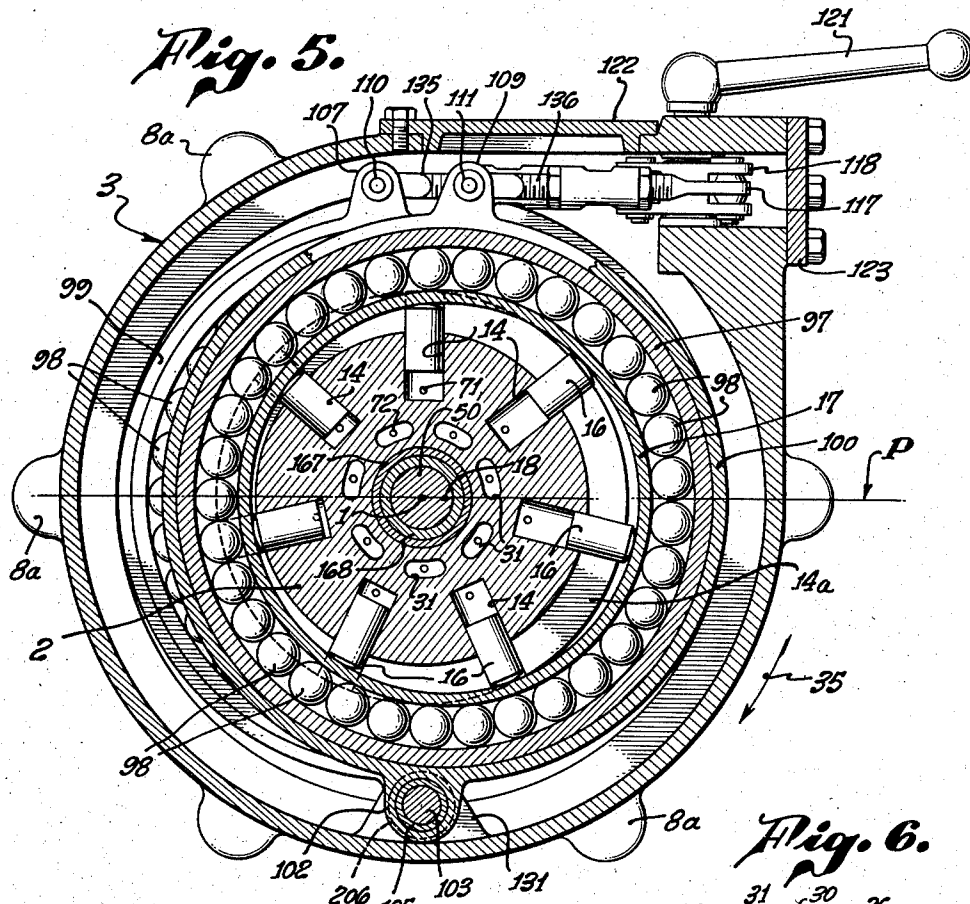
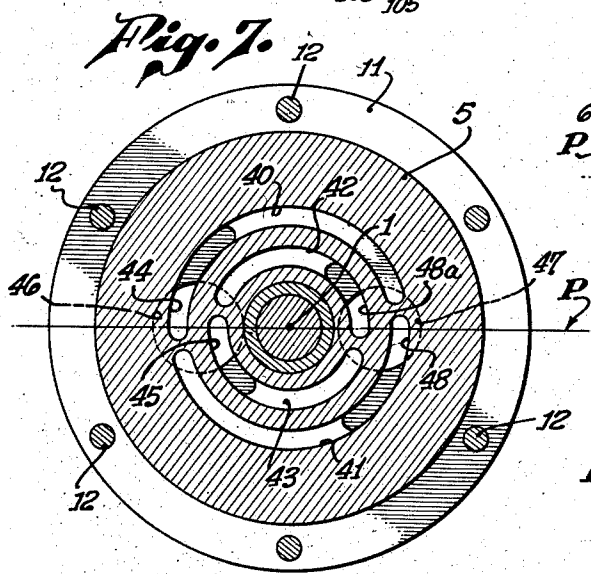
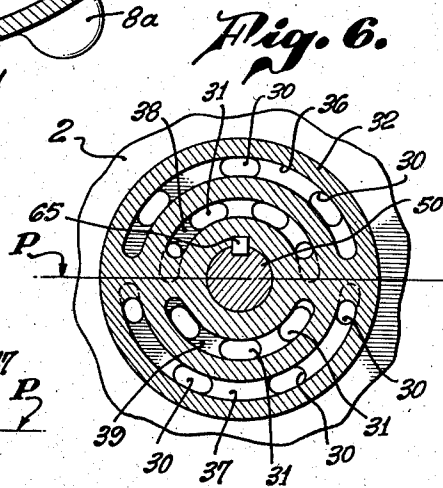
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4 Sheets-Sheet 3



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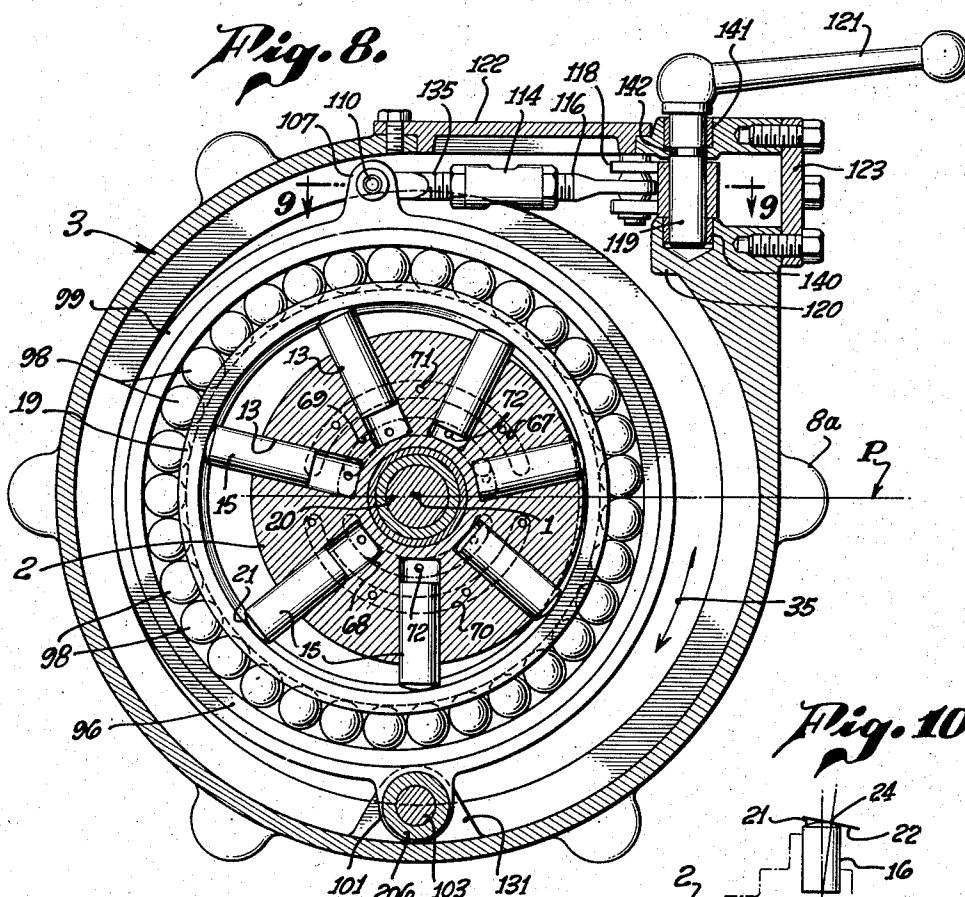
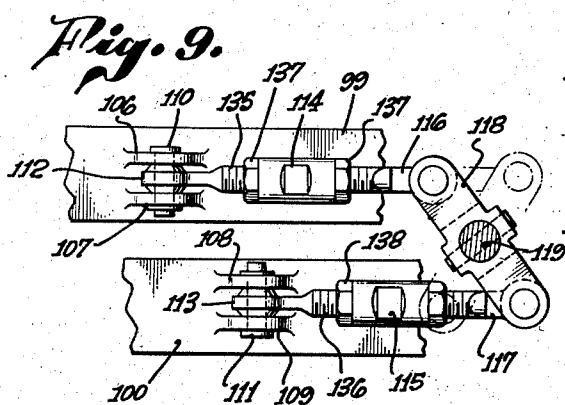
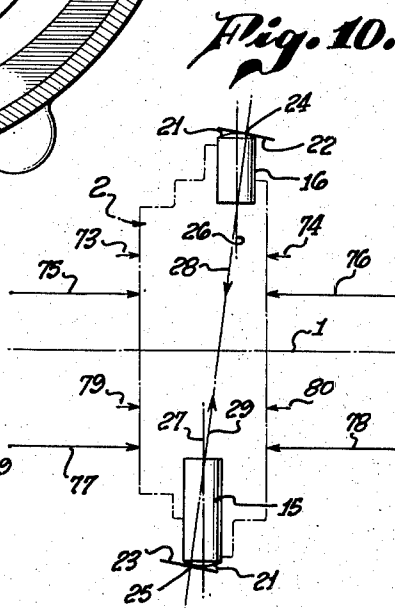
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4 Sheets-Sheet 4



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HYDRAULIC APPARATUS UTILIZING ROTARY CYLINDER BLOCKS

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Application December 27, 1952, Serial No. 328,214

5 Claims. (Cl. 103—161)

This invention relates to hydraulic apparatus, capable of being used either as a pump or a hydraulic motor.

A known type of apparatus of this general character utilizes a rotary cylinder block, provided with generally radially disposed cylinder chambers opening at the periphery of the block. These chambers are usually equiangularly spaced about the axis of rotation. Pistons operate in these chambers, and are caused to reciprocate therein by the aid of a reaction ring having an axis eccentric to the axis of the block. The outer ends of the pistons are in contact with the eccentric inner surface of the ring. Accordingly, as the block rotates, the radial movement of the pistons outwardly is limited by this inner eccentric surface, and the pistons accordingly move inwardly and outwardly of the cylinder chambers as they contact the eccentric surface at a place closer to and further from the block axis.

Appropriate ports are formed in cylinder block and in the walls between which the block is confined, to lead fluid or liquid into and out of the cylinder chambers in proper sequence. Thus let it be assumed that a plane passes through the block axis and center of the reaction ring. When operating as a pump, all of the cylinder chambers at any instant on one side of that plane are in communication with an inlet passage; and all of the cylinder spaces on the other side of that plane are in communication with an outlet passage. In such a case, these latter chambers contain liquid under higher pressure than the other chambers.

When operating as a motor, the inlet and outlet passages are interchanged, the inlet passage in this instance carrying the higher pressure.

In either case, the preponderance of pressure on one side of the plane with respect to the other produces undesirable results. Since the pump or motor may be operating at pressures of several thousand pounds per square inch, the resultant force transverse to the axis of rotation imposed on the bearings for the rotating cylinder blocks is very heavy, and correspondingly heavy bearing structure must be used to sustain this load. In addition, this force produces a turning couple tending to tilt the rotary members about an axis normal to the axis of rotation. Additional loads would be thus imposed upon the cylinder block and its supports, producing flexures that militate against efficient operation of the mechanism.

It is one of the objects of this invention to make it possible effectively to neutralize these forces, whereby simple and inexpensive bearing structures may be utilized, and whereby bending forces are also substantially eliminated.

In order to accomplish these results, use is made of a double set of cylinder chambers and pistons, the sets being axially spaced, each of the sets of pistons cooperating with its own eccentric reaction ring. The eccentricities of the two rings are maintained equal but on opposite sides of the cylinder block axis. The rings and pistons are arranged to produce forces on the block that are of the proper direction and amount substantially to

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nullify or neutralize them; and the net resultant force is a mere force of compression on the cylinder block, which is usually rigid enough to sustain this load without special design.

Accordingly, it is another object of this invention to provide a simple and efficient structure of this character.

One manner of rotatably supporting the cylinder block includes the provision of a stationary spacer corresponding in axial length with the width of the block. A non-rotary valve plate may be provided adjacent each side of the block, for providing ports connecting with the inlet and outlet passages. Under such circumstances, unbalanced hydraulic pressure forces are present that are in a direction to flex the support upon which the spacer is mounted.

The resultant strain or bending would result in loss of pumping efficiency.

It is, therefore, another object of this invention to make it possible to balance these forces, so that their harmful effects are eliminated.

The spacer support is preferably in the form of a non-rotary shaft or stud. The spacer mounted on the stud is so proportioned that a running clearance is maintained between the sides of the rotary cylinder block and the adjacent surfaces of the plates. The hydraulic pressures exerted between the plates and the block produce a tensioning stress on the stud, elongating it. The result is that the running clearance is increased to an intolerable degree.

It is still another object of this invention to neutralize this tensioning stress in a simple and effective manner.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of one embodiment of the invention. For this purpose there is shown a form in the drawings accompanying and forming part of the present specification. The form will now be described in detail, illustrating the general principles of the invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of this invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is an end view of an apparatus incorporating the invention;

Fig. 2 is a horizontal sectional view, taken along a plane corresponding to line 2—2 of Fig. 3;

Fig. 3 is a sectional view taken along a plane corresponding to line 3—3 of Fig. 1;

Figs. 4, 5, 6, 7 and 8 are sectional views, taken along planes corresponding respectively to lines 4—4, 5—5, 6—6, 7—7, and 8—8 of Fig. 3;

Fig. 9 is a fragmentary sectional view, taken generally along a plane corresponding to line 9—9 of Fig. 8; and

Fig. 10 is a diagram illustrating the manner in which the forces produced by hydraulic pressure are balanced or neutralized.

The apparatus will be described as a pump structure, although by appropriate choice of the inlet and outlet conduit, it may be used as a hydraulic motor.

The main axis 1 of the device serves as a center of rotation for a cylinder block 2. This cylinder block is enclosed in a casing having a main member 3 of generally cylindrical configuration. This cylinder casing member 3 is closed at its left hand end by the aid of a cover member 4. A cover member 5 closes the right hand end.

All of these three members, 3, 4, and 5, may appropriately be made from castings such as of an aluminum alloy.

The cover member 4 is in fluid tight relationship with the casing 3 as by the aid of an O-ring 6 (Fig. 3) disposed in an annular groove in a flange 7 formed integrally with cover member 4. This flange 7 telescopes within the

member 3. Appropriate machine screws 8 (Fig. 2) engage threaded bosses 8a on member 3 to attach the cover member 4 to the casing member 3. Similarly, the casing member 3 at its right hand end is provided with an internal flange 9 (Figs. 2 and 3) into which telescopes the cylindrical portion 10 of the cover member 5. An external flange 11 of this cover member serves as a means for attaching the cover member to the right hand end of the casing member 3 as by the aid of the machine screws 12.

The cylinder block 2 is provided with two sets of radially arranged cylinder chambers. One set of the cylinder chambers, designated by reference character 13, is spaced axially with respect to the other set of cylinder chambers 14 (see particularly Figs. 2 and 3). Each set of cylinder chambers comprises in this instance seven equiangularly spaced chambers. Since there is an odd number of chambers in each of these sets 13 and 14, the arrangement can be such that for any cylinder chamber 13, there is a diametrically opposite cylinder chamber 14. This is accomplished by offsetting the angular spacing of one cylinder chamber in one set with respect to the other set by one-half of the angular spacing of the cylinders of each set. For example, viewing Figs. 5 and 8, it is seen that the upwardly directed cylinder chamber 14 of the right-hand set (Fig. 5) is diametrically opposite the downwardly directed cylinder chamber 13 of the left-hand set (Fig. 8).

Each set of cylinder chambers is provided with corresponding piston structures; thus the left-hand set shown in Fig. 8 comprises the piston structures 15; and the right-hand set comprises the piston structures 16 (Fig. 5).

Each of these sets of pistons is adapted to cooperate with its own reaction ring placed upon a center eccentric with respect to the axis 1.

Thus, considering first the right-hand set of cylinder chambers 14, with its corresponding set of pistons 16, a reaction ring 17 is provided for causing the pistons to reciprocate as the cylinder block 2 rotates. The reaction ring 17 for the specific adjustment illustrated in Fig. 5 has a center 18 spaced to the right of the axis of rotation 1.

A corresponding reaction ring 19 (Figs. 2 and 8) is provided for the set of pistons 15. In this instance, however, the center 20 of the reaction ring 19 is spaced from the axis 1 to the left by an amount equal to the distance between the axis 1 and the center 18. Thus the two eccentric reaction rings are equally and oppositely eccentric with respect to the axis of rotation 1. Furthermore, each of the piston structures 15 and 16 is provided with an end spherical contacting surface 21. Surfaces 21 provided on the sets of piston structures 16 cooperate with a tapered or conical surface 22 of the reaction ring 17 (Figs. 2 and 10). Similarly, the sets of piston structures 15 cooperate with a corresponding tapered or conical surface 23 of the reaction ring 19.

As shown most clearly in Fig. 10, the points of contact 24 and 25 respectively between the sloping surfaces and the piston structures 16 and 15 are spaced from the center axes 26 and 27 of the piston structures. Accordingly, as the cylinder block 2 rotates the slight frictional forces at the points of contact serve to impart a rotation to these piston structures about their axes.

The piston structures 15 and 16 are urged outwardly either by centrifugal force or by liquid pressure in the cylinder chambers so as to urge the spherical surfaces 21 into contact with the tapered surfaces 22 and 23.

Each of the cylinder chambers 14 in the right-hand set is provided with a port 30 (Figs. 2 and 3) which extends in a direction parallel to the axis 1 and arranged annularly as illustrated in Fig. 6. All of these ports open at the right-hand side of block 2. The left-hand cylinder chambers 13 are similarly provided with ports 31. These ports 31 are also arranged annularly and located on

a circle of smaller diameter than the circle upon which the ports 30 are located (Fig. 6).

These ports 30 and 31 communicate as shown most clearly in Fig. 2 with the inner end of their respective cylinder spaces. The reaction rings 17 and 19 extend laterally above the cylinder chambers. Semicircular extensions of these chambers are formed by the edges 13a and 14a; these extensions project radially outwardly beyond these rings 17 and 19. Accordingly, these extensions serve well to sustain the thrust exerted by the reaction of the rings in the pistons, since these extensions are disposed diametrically opposite the place where the sloping surfaces 22 and 23 of rings 17 and 19 contact the pistons 16 and 15. The cylinder bores are thus relieved against undue strain produced by transverse forces that may act on the piston structures. There is thus no danger that the chambers will assume an undesired elliptical shape.

A valve plate 32 (Figs. 2, 3 and 6) appropriately controls the inward and outward flow of liquid into and out of the cylinder chambers 13 and 14. This valve plate 32 is non-rotary. It is attached to the inner face of the cover member 5 as by the aid of the screws 33 (Fig. 2) which pass through a flange 34 at the right-hand end of the valve plate 32.

Assuming that a plane P (Figs. 5, 6 and 8) is passed through the axis 1 and the centers 18 and 20 of the reaction rings 17 and 19 respectively, then those ports 30 that happen at any instance to be on opposite sides of this plane, communicate respectively with the inlet or outlet of the pump structure. Thus, for example, if the cylinder block 2 rotates in a clockwise direction as indicated by arrow 35 (Figs. 5 and 8), and the apparatus operates as a pump, then those ports 30 which are above the plane P communicate with the inlet, while those ports 30 which are below the plane P communicate with the outlet. Thus the effective volume of the cylinder spaces 14 that are located above the plane P gradually increases in the direction of rotation (Fig. 5); and this volume gradually decreases as the cylinder spaces cross the plane P.

Now considering the left-hand set of cylinder chambers 13 shown in Fig. 8, the cylinder ports 31 below the plane P are connected to the inlet, and those above the plane P are connected to the outlet. Thus viewing Fig. 8, it is seen that the effective volume of the cylinder chambers 13 below the plane P increases in the direction of rotation, while the effective volume of those cylinder chambers 13 above the plane P decreases in the direction of rotation.

These relationships are directly due to the equal and opposite eccentricities of the reaction rings 17 and 19. The increase in volume in each instance corresponds to the intake stroke, and the decrease in volume to the exhaust stroke.

The valve plate 32 in conjunction with the cover member 5 serves to provide the appropriate inlet and outlet passages to the sets of ports hereinabove referred to.

Thus the valve plate 32 for the ports 30 has a pair of through kidney ports 36 and 37 (Figs. 3 and 6) extending diametrically opposite to each other and in a symmetrical fashion about the axis 1 and the plane P. The kidney port 36 extends above the plane P and the kidney port 37 below it. The kidney port 36 is in communication with an inlet conduit in a manner to be hereinafter described, while the kidney port 37 is in communication with an outlet conduit.

Similarly, another pair of through kidney ports 38 and 39 is provided for the cylinder ports 31 of the right hand set of cylinder spaces 14. These ports 38 and 39, as shown most clearly in Fig. 6, are located within the ports 36 and 37, and are arranged symmetrically with respect to plane P. In this instance the upper kidney port 38 is in communication with the outlet conduit, and the lower kidney port 39 is in communication with the inlet. Furthermore, the angular arrangement with the

ports 38 and 39 is substantially the same as the angular arrangement of the kidney ports 36 and 37.

Accordingly, while any one of the cylinder chambers 14 of the right-hand set is in communication with either the inlet or outlet via ports 36 or 37, there is a corresponding diametrically opposite cylinder chamber 13 of the left-hand set also in communication with the inlet or outlet, via ports 39 or 38. Accordingly, the forces 28 and 29 (Fig. 10), due to the pressure in each such pair of cylinder chambers, are equal and opposite; furthermore, these forces are in alignment due to the location of the points of contact between the spherical surfaces 21 and the conical surfaces 22 and 23. A substantially complete neutralization of these forces is thus effected for all angular positions of the cylinder block 2.

Therefore, the ultimate force resultant is such that rings 17 and 19 are subjected, by the reaction against these rings, to an expanding force, while the cylinder block 2 is subjected to simple compression by the forces 28 and 29. No rotating effect or torque is produced thereby, on an axis normal to axis 1.

The kidney ports 36, 37, 38 and 39 in the valve plate 32, as heretofore explained, extend completely through this plate, as indicated most clearly in Fig. 3. These ports are in communication respectively with the deep kidney shaped grooves 40, 41, 42 and 43 disposed in the cover member 5. These deep grooves are in register with their respective ports 36, 37, 38 and 39 (see also Fig. 7). However, these grooves have a slightly greater angular extent than the corresponding ports in order to provide a substantial passage to the spaces that lead to the inlet and outlet conduits.

An inlet opening 46 (Figs. 1 and 2) is formed in a raised boss 46a (Fig. 1). This opening is located on an axis angling inwardly toward axis 1. Its outer end is threaded in order to accommodate an appropriate conduit leading from a source of liquid to be operated on by the pump structure. This opening 46 as shown most clearly in Figs. 1 and 7 communicates with two short kidney shaped ports or slots 44 and 45 which open into the left hand face of member 5. The slot 44 communicates with the groove 40 that is aligned with the inlet port 36 of valve plate 32. Similarly, port or slot 45 communicates with the inlet port 43. In Fig. 7, those portions of the openings of these ports or slots 44, 45 that are not in registry with inlet 46 are shaded.

An outlet opening 47 is arranged on the opposite side of the boss 46a and is angled similarly to the inlet opening 46 (Fig. 2). It communicates with the through slots or ports 48 and 48a (Figs. 1 and 7) in order to establish communication between the kidney shaped grooves 41 and 42, and the outlet 47.

In order to confine the cylinder block 2 in fluid type relationship with respect to the inlet and outlet port structures, this cylinder block is confined between two plane surfaces. At its right-hand side, it is confined by the left-hand face of the non-rotary valve plate 32. Its left-hand side is confined by the right-hand surface of a balance plate 49 (Figs. 2 and 3). This balance plate is held against the left-hand face of the cylinder block 2 and is restrained against rotation.

The main support for the cylinder block 2 is provided by a cylindrical non-rotary stud member 50, disposed on the axis 1. This stud member 50 extends through a bushing 51 that is threaded at its left-hand end into the valve plate 32. At its right hand end it has a flange 52 that is seated in a counterbore in the cover member 5.

At its left-hand end the stud 50 is provided with a head 53 (Fig. 3) that serves as an abutment for a reaction member 54, the function of which will be described hereinafter. This reaction member 54 is placed in fluid-tight relationship with the balance plate 49 as well as with the stud 50. For this purpose the plate 49 is provided with a grooved flange 55 that telescopes within the flange

56 of the member 54. An O-ring 57 is interposed between the flange 56 and the bottom of the groove in flange 55.

Similarly, an O-ring 58 is disposed around the stud 50 and is accommodated in the groove 59 of the hub 60 formed on the member 54. A curved spring washer 61 is interposed between this hub and the balance plate 49 in order to provide a slight spring pressure urging the plate 49 toward the block 2.

The right-hand end 62 of the stud 50 is threaded and projects through the sleeve 51. A nut 63 is threaded on the portion 62 to urge the stud 50 to engaging position. Washer 64 may be interposed between the nut and the flange and the end of the sleeve 51. In order to lock the nut in place a cross pin 65 is provided.

In order to restrain the valve plate 32 and the balance plate 49 against rotation, they may be keyed to the stud 50 by the aid respectively of the keys 65 and 66. (See Figs. 4 and 6.) Furthermore, these keys insure that the proper angular relationship is maintained between these two plates.

The cylinder block 2 is rotatably supported on the stud 50 by the aid of a sleeve 167 pressed into the block 2, and disposed over a spacer sleeve 168. This sleeve 168 contacts the opposed faces of the valve plate 32 and the balance plate 49, and maintains the spacing of these two plates by an amount slightly in excess of the thickness of the cylinder block 2. This clearance may be of the order of .004 inch. Such a clearance will maintain the pump structure against appreciable leakage losses. Due to this feature, and the provisions of the sealing O-rings 57 and 58, there is no appreciable loss of liquid into the casing structure.

Without further provisions, the pressure exerted upon the cylinder block 2 by the liquid pressure in the passages formed by the ports 36, 37, 38 and 39, and by grooves 40, 41, 42 and 43, would urge the cylinder block 2 toward the left against plate 49. Still another undesirable effect, if not neutralized, would occur. This effect will now be described.

Groove 41 (Fig. 7) and port 37 carry high fluid pressures, since they are in communication with the outlet 47. The corresponding upper groove 40 and port 36 carry low pressure fluid. The net result may be represented by the forces 78 and 74 of Fig. 10. The force 74 is shown greatly exaggerated, in comparison with force 78. The unbalanced resultant is such as to produce a torque on an axis normal to axis 1 in a counter-clockwise direction. Similarly, the forces 76 and 80 represent the resultants of the pressures imposed upon block 2 by the liquid in the outlet port 38 and the inlet port 39. It is clear that these four forces have a net resultant that has a direction below the axis 1 and parallel thereto, setting up a turning force tending to move the block 2 in a counter-clockwise direction about an axis perpendicular to axis 1.

In order to neutralize this torque and to balance the pressures, grooves 67, 68, 69 and 70 are disposed in the right-hand face of the plate 49 (Fig. 4). These grooves have the identical form and location of the ports 36, 37, 38 and 39 respectively. The fluid pressure in groove 67 is made to correspond to the fluid pressure in the opposite port 36, thereby neutralizing the hydraulic force, due to fluid pressure in port 36. Similarly, the fluid pressures in groove 68 and port 37 correspond; the fluid pressures in groove 69 and port 38 correspond, as do the pressures in groove 70 and port 39.

For this purpose, each and every one of the cylinder spaces 14 is provided with a small port 71 (Figs. 3 and 5) that lead either to the groove 67 or 68. Accordingly, the pressures in grooves 67 and 68 correspond substantially with the pressures in the ports 36 and 37.

Similarly, the inner grooves 69 and 70 are in communication with the cylinder spaces 13 by the aid of the

ports 72 (Figs. 5 and 8). The pressures in these grooves correspond to the pressures in ports 38 and 39.

These opposing forces set up by the pressures are indicated diagrammatically in Fig. 10, where the force 73 corresponding to the force exerted by the fluid in groove 67, is of the same magnitude as the force 74 corresponding to the fluid pressure in the port 36. These forces are thus neutralized. The forces 75 and 76 are opposite and equal and correspond respectively to the fluid pressures in the groove 69 and the valve port 38. Similar pairs of forces 77 and 78 correspond respectively to equal and opposite fluid pressures in the groove 68 and the port 37. The forces 79 and 80 correspond respectively to equal and opposite pressures in the groove 70 and the port 39. Accordingly, there is a substantially perfect balance of forces, eliminating any turning moment about an axis transverse to axis 1. Forces 28 and 29, represented in Fig. 10, due to the reaction between the piston structures 16 and 15 respectively upon the reaction rings 17 and 19, are in alignment linearly and directionally so that they neutralize each other.

Because of the balancing of the forces 28, 29, due to the fluid pressures in the cylinder chambers, and the balancing of the forces 73 to 80 (Fig. 10), no substantial bearing load is imposed upon the stud 50. The simple sleeve 67 is all that is required for maintaining the cylinder block 2 in proper axial position.

Another force tends to urge plates 32 and 49 apart. This force is created by pressure against the right-hand face of the plate 49 and the pressure against the left-hand face of the valve plate 32. Due to the extremely high pressure of the liquid passing through the pump, such force, if uncompensated, would increase the clearance between the cylinder block 2 and the plates 32 and 49. To balance this force, fluid under outlet pressure is exerted on the left-hand side of the balance plate 49. For this purpose a port 81 (Figs. 3 and 4) extends from the groove 69 to the left-hand side of the plate 49. The space between the reaction member 54 and the plate 49 is thus subjected to outlet pressure. This pressure is effective upon an annular area corresponding to the internal diameter of the flange 56 and the diameter of the stud 50. The magnitude of this area is purposely chosen to provide substantially complete equalization of the pressure urging the plates 32 and 49 apart. Accordingly, the clearance maintained between opposed faces 32 and 49 is unaffected.

In order to drive the cylinder block 2, a sleeve 82 is provided which has two axially spaced sets of splines on its internal surface. The right-hand set of splines 83 cooperates with the splines 84 formed at the left-hand reduced portion of the cylinder block 2. The left-hand set of splines 83a of sleeve 82 of similar configuration cooperates with the splines formed on the periphery of a flange 85 formed integrally with a rotary driving member 86. A spring ring 87 engages an internal groove intersecting the splines 83a on the inner periphery of the sleeve 82 for restricting axial movement of the sleeve.

The driving member 86 is appropriately supported for rotation by the thrust ball-bearing structures 88 and 89. The outer races for these ball-bearing structures are held firmly in place in the hub 90 of the cover member 4 as by the aid of a cage 91. The outer races are press-fitted into this cage, which is in turn press-fitted into hub 90. The inner races are affixed to the drive member 86, as by the aid of a nut 92 threaded on the drive member 86. This nut urges the races against a shoulder formed on the drive member. The nut is locked by the aid of a locking member 93 having a lip engaging in a groove on the exterior of the nut, and another lip engaging in a groove in the drive member.

The drive member 86 is provided with internal splines 94 for the accommodation of a drive shaft 95.

A flanged supplemental cover member 130 is tele-

scoped within the hub 90 for maintaining the outer races in axial position.

The reaction rings 17 and 19 are supported by anti-friction elements in the outer races 96 and 97. Between these outer races 96 and 97 are disposed the rolling elements, such as the balls 98, to provide substantially frictionless movement of the reaction rings (Figs. 2 and 3).

The outer races 96 and 97 are press-fitted in the flanged rings 99 and 100 (see also Fig. 5). Each of these rings has an end flange. These flanged rings are arranged so that their eccentricities may be adjusted. For this purpose they are pivotally mounted by the aid of ears 101 and 102 upon a pin 103 extending through these ears. This pin is rigidly mounted within casing member 3 to extend parallel to axis 1 by the aid of ear 131 (Figs. 3 and 5) and a rear boss 132. Interposed between the pin 103 and the ears 102 are the bearing bushings 104 and 105. A spacer collar 206 serves to keep these rings 99 and 100 in axially spaced relation.

Since the axis of the pin 103 is parallel to but spaced considerably below the axis 1, angular movement of the rings 99 and 100 about the axis of pin 103 causes adjustment of the eccentricities of these rings. Equal and opposite adjustment of these rings about that axis can be effected in any conventional manner. One specific means for accomplishing this is shown most clearly in Figs. 5, 8 and 9.

Thus, each of the rings 99 and 100 is provided with a pair of apertured ears 106, 107, 108 and 109. These ears are located diametrically opposite the ears 101 and 102. They serve to accommodate the pivot pins 110 and 111. These pivot pins extend respectively through the eyes 112 and 113 of turnbuckle screws 135 and 136. These screws engage turnbuckle bodies 114, 115. The threaded eyes 116 and 117 are located at the other end of these bodies 114, 115. By the aid of the nuts 137, 138, the adjusted lengths of the turnbuckle structures can be maintained. The eyes 116, 117 are provided with ears pivotally joined to the opposite ends of an arm 118. This arm 118 is fastened to a vertical post 119 rotatably supported in the boss 120 of casing member 3. Bearing bushings 140, 141 are provided for this post, located respectively in the boss 120 and the upper wall of casing member 3. A spring ring 142 is disposed in a groove of the post to cooperate with the lower surface of bushing 141 to limit axial movement of the post.

The post is provided with an external handle 121 for adjusting the position of the arm 118. Any appropriate restraint for holding the handle in adjusted position may be provided. Thus, by operating the handle 121, the degree of eccentricity of the reaction rings 17 and 19 may be adjusted equally and oppositely with respect to the axis 1. Such adjustment serves to adjust the length of the piston strokes.

To gain access to the turnbuckle structures, a cover plate 122 for the casing 3 is provided. An auxiliary cover plate 123 also assists in gaining access for adjustment and installation of the turnbuckle parts. The adjustability provided by the turnbuckles makes it possible to ensure accurate equal and opposite adjustments of the eccentricities of the reaction rings 17, 19.

The inventor claims:

1. In hydraulic apparatus of the character described: a cylinder block rotatable about an axis; said block having two sets of cylinder chambers, said sets being axially spaced along the block axis; said chambers being radial to said axis; piston structures in said chambers; a pair of reaction rings respectively for the sets of piston structures, said rings having substantially equal and opposite eccentricities with respect to the block axis; each piston structure of one set being diametrically opposite a corresponding piston structure of the other set; the reaction rings having annular sloping surfaces of contact for the piston structures such that the direction of the forces

between the piston structures and the ring of one set align respectively with the forces corresponding to diametrically opposite piston structures of the other set; said cylinder block having individual ports respectively to the cylinder chambers, and annularly arranged; the ports for one set of chambers being located on a circle of different diameter than the ports for the other set of chambers; and all of the ports opening on one side of the cylinder block; and a non-rotary valve plate facing said one side and having two pairs of kidney ports respectively for the sets of cylinder ports, the pair of kidney ports for the inner annular series of cylinder ports corresponding in radial position with the inner series of cylinder ports, and the pair of kidney ports for the outer annular series of cylinder ports corresponding in radial position with the outer series of cylinder ports.

2. In hydraulic apparatus of the character described: a cylinder block rotatable about an axis; said block having two sets of cylinder chambers, said sets being axially spaced along the block axis; said chambers being radial to said axis; piston structures in said chambers; a pair of reaction rings respectively for the sets of piston structures, said rings having substantially equal and opposite eccentricities with respect to the block axis; each piston structure of one set being diametrically opposite a corresponding piston structure of the other set; the reaction rings having annular sloping surfaces of contact for the piston structures such that the directions of the forces between the piston structures and the ring of one set align respectively with the forces corresponding to diametrically opposite piston structures of the other set; said cylinder block having individual ports respectively to the cylinder chambers, and annularly arranged; the ports for one set of chambers being located on a circle of different diameter than the ports of the other set of chambers; and all of the ports opening on one side of the cylinder block; a non-rotary valve plate facing said one side, having two pairs of kidney ports respectively for the sets of cylinder ports, the pair of kidney ports for the inner annular series of cylinder ports corresponding in radial position with the inner series of cylinder ports, and the pair of kidney ports for the outer annular series of cylinder ports corresponding in radial position with the outer series of cylinder ports; and a non-rotary balance plate facing the other side of the cylinder block and having kidney shaped annular recesses corresponding in size and position with the kidney ports; the cylinder chambers of one set that have ports arranged on the outer annular circle, having supplemental ports leading to the outer annular recesses; and the cylinder chambers of the other set having supplemental ports leading to the inner annular recesses.

3. In hydraulic apparatus of the character described: a cylinder block rotatable about an axis; said block having radial cylinder chambers opening at the periphery of the block; said chambers having ports leading to one side of the block; piston structures in said chambers; a non-rotary central support for the block; said support being anchored at one end only; a spacer sleeve on the support and extending through the block; plates defining ports and passageways communicating with the cylinder chambers and disposed on opposite sides of the block; that plate remote from the anchored end having a surface opposite the surface adjacent the side of the block; and means forming a pressure chamber with said opposite surface; there being passage means for subjecting said space to hydraulic pressure, and the area of said opposite surface being such as to cause counterbalance of the pressures urging the plates apart.

4. In hydraulic apparatus of the character described: a cylinder block rotatable about an axis; said block having two sets of cylinder chambers, said sets being axially spaced along the block axis; said chambers being radial to said axis; piston structures in said chambers; a pair of reaction rings respectively for the sets of piston structures, said rings having substantially equal and opposite eccentricities with respect to the block axis; each piston structure of one set being diametrically opposite a corresponding piston structure of the other set; the ports for one set of chambers being located on a circle of different diameter than the ports for the other set of chambers; and all of the ports opening on one side of the cylinder block; and a non-rotary valve plate facing said one side and having two pairs of kidney ports respectively for the sets of cylinder ports, the pair of kidney ports for the inner annular series of cylinder ports corresponding in radial position with the inner series of cylinder ports, and the pair of kidney ports for the outer annular series of cylinder ports corresponding in radial position with the outer series of cylinder ports.

5. In hydraulic apparatus of the character described: a cylinder block rotatable about an axis; said block having two sets of cylinder chambers, said sets being axially spaced along the block axis; said chambers being radial to said axis; piston structures in said chambers; a pair of reaction rings respectively for the sets of piston structures, said rings having substantially equal and opposite eccentricities with respect to the block axis; each piston structure of one set being diametrically opposite a corresponding piston structure of the other set; said cylinder block having individual ports respectively to the cylinder chambers, and annularly arranged; the ports for one set of chambers being located on a circle of different diameter than the ports for the other set of chambers; and all of the ports opening on one side of the cylinder block; a non-rotary valve plate facing said one side, having two pairs of kidney ports respectively for the sets of cylinder ports, the pair of kidney ports for the inner annular series of cylinder ports corresponding in radial position with the inner series of cylinder ports, and the pair of kidney ports for the outer annular series of cylinder ports corresponding in radial position with the outer series of cylinder ports; and a non-rotary balance plate facing the other side of the cylinder block and having kidney shaped annular recesses corresponding in size and position with the kidney ports; the cylinder chambers of one set that have ports arranged on the outer annular circle, having supplemental ports leading to the outer annular recesses; and the cylinder chambers of the other set having supplemental ports leading to the inner annular recesses.

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