Aug. 7, 1945. C. E. GROSSER 2,381,741

PUMP OR MOTOR UNIT

Filed Oct. 22, 1942 3 Sheets-Sheet 1

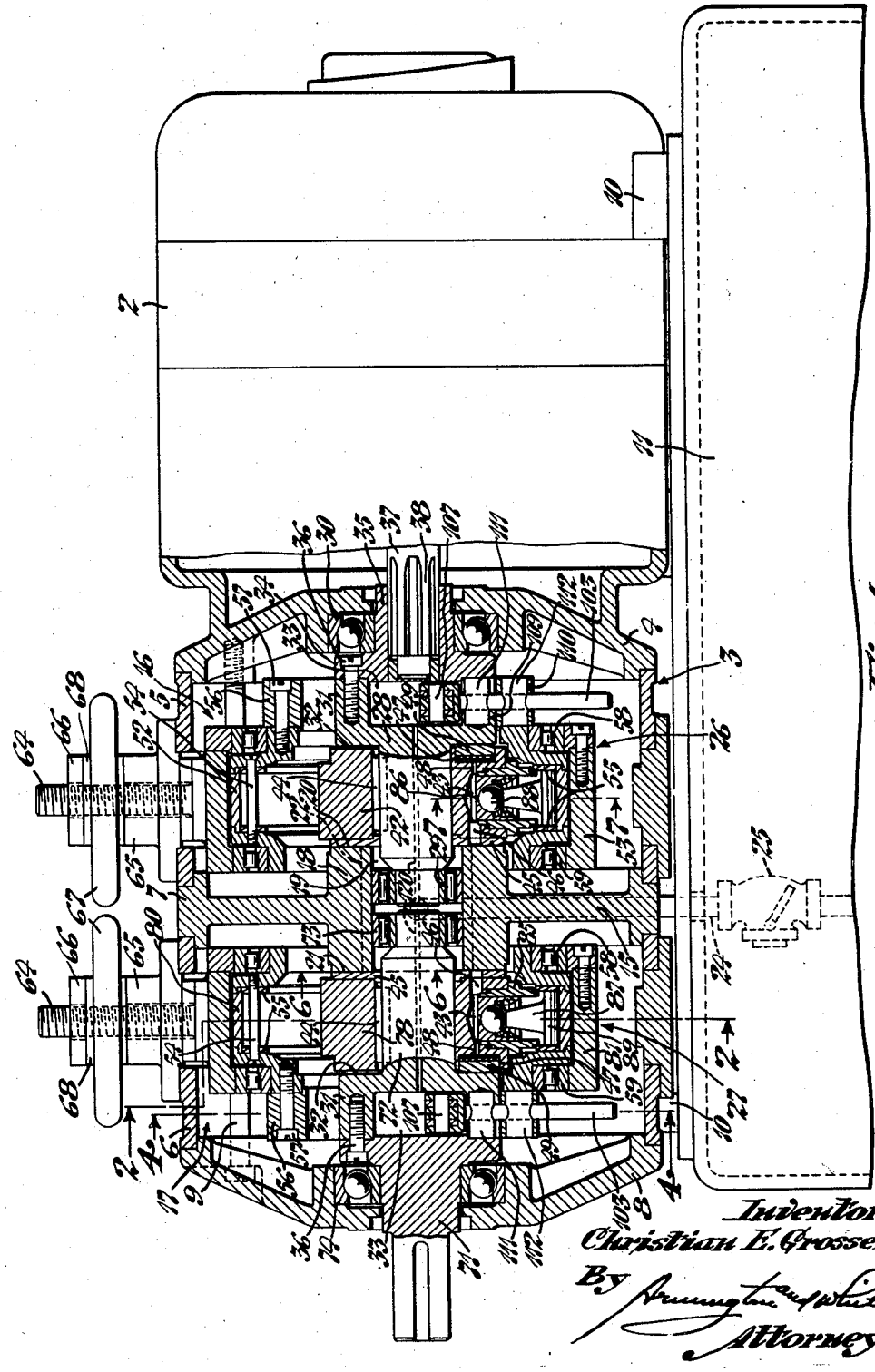


Fig. 1.

Inventor:
Christian E. Grosser
By Brumbaugh, Graves, Donohue & Raymond
Attorneys.

Aug. 7, 1945. C. E. GROSSER 2,381,741

PUMP OR MOTOR UNIT

Filed Oct. 22, 1942 3 Sheets-Sheet 2

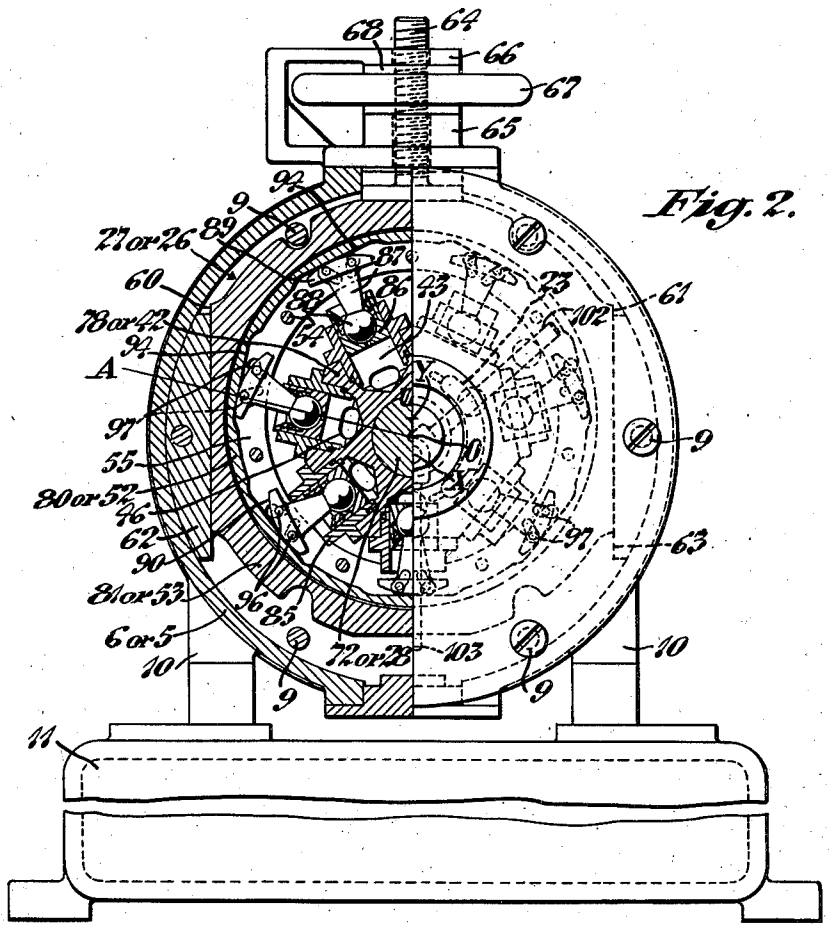


Fig. 2.

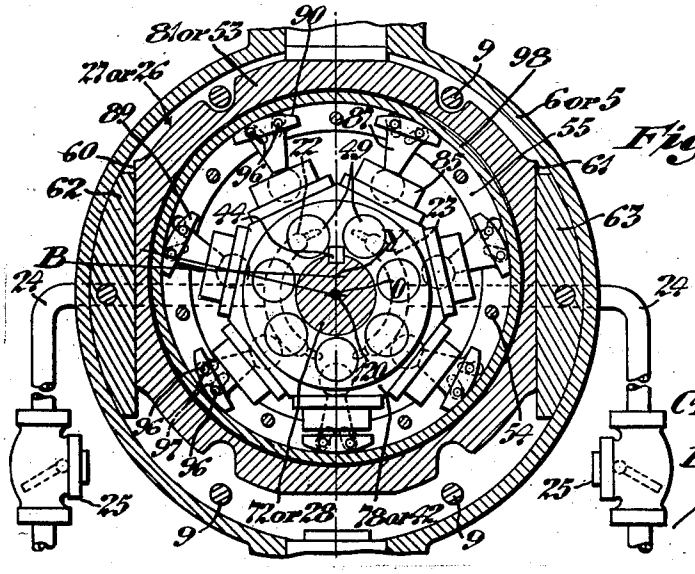


Fig. 3.

Inventor:
Christian E. Grosser
By Pennington and White
Attorneys.

Aug. 7, 1945. C. E. GROSSER 2,381,741

PUMP OR MOTOR UNIT

Filed Oct. 22, 1942 3 Sheets-Sheet 3

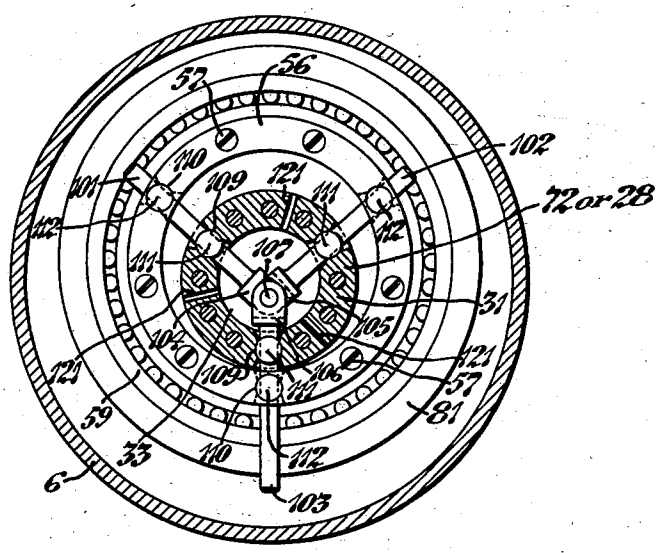


Fig. 4.

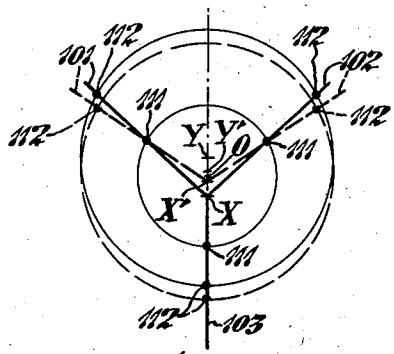


Fig. 5.

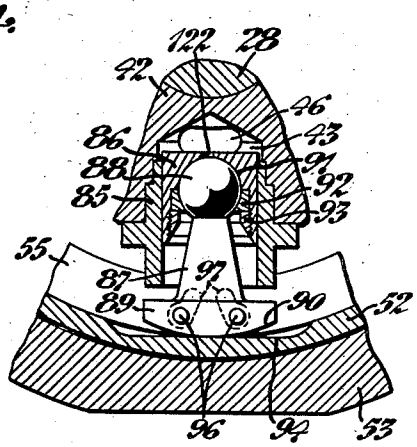


Fig. 7.

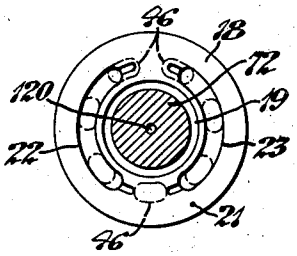


Fig. 6.

Inventor:
Christian E. Grosser
By Cummings & White
Attorneys.

Patented Aug. 7, 1945 2,381,741

UNITED STATES PATENT OFFICE

2,381,741

PUMP OR MOTOR UNIT

Christian E. Grosser, Winchester, Mass., assignor to Standard Machinery Company, Cranston, R. I., a corporation of Rhode Island

Application October 22, 1942, Serial No. 462,939

18 Claims. (Cl. 103—161)

The present invention relates to hydraulic variable-speed power-transmission apparatus and more particularly to improvements in the pump and motor units of such apparatus.

One of the objects of the present invention is to provide an apparatus of the type indicated having variable-displacement pump and motor units of the type in which radial cylinders and a reaction ring rotate in unison about eccentric axes.

Another object is to provide a pump or motor unit of the type indicated with piston-rods having rocker-bearings adapted to rock on the reaction ring surrounding the cylinders to compensate for the relative movement between the cylinders and ring during their rotation about eccentric axes.

Another object is to provide a pump or motor unit of the type indicated with piston-rods pivotally connected at one end to their respective pistons and having arcuate rocker-bearings at their opposite end concentric with their pivotal connection to the pistons and engageable with the ring tangentially.

Another object is to provide a motor or pump unit of the type indicated in which the contact faces of the reaction ring and the contact faces of the rocker-bearings of the piston-rods are so formed as to cause their points of tangential engagement to aline with the axes of their respective cylinders in any angular position of the piston-rods.

Another object is to provide a novel form of coupling for connecting the cylinder-block and reaction ring for rotation as a unit about eccentric axes.

Another object is to provide a coupling of the type indicated having radial arms which connect the eccentric members for rotation and which rock on a fixed pivot for any particular adjustment of the eccentricity.

Another object is to provide a radial pump or motor unit of the type indicated with cooperating ported valve-members on the cylinder-block and enclosing casing for controlling the intake and exhaust of motive fluid.

Another object is to provide a pump or motor unit of the type indicated with means operated by the motive fluid for applying a predetermined axial thrust to the cylinder-block to hold the valve-members in engagement.

Another object is to provide a hydraulic power-transmission apparatus having pump and motor units in the same casing cooperating with the opposite sides of a single valve-annulus.

Still another object is to provide an apparatus of the type indicated which is of simple and compact construction, efficient in performing its intended functions and adapted for use over long periods of time without requiring repair or replacement of its parts.

Further objects of the invention are set forth in the following specification which describes several forms of construction of the apparatus, by way of example, as illustrated by the accompanying drawings. In the drawings:

Fig. 1 is a part-sectional elevational view of a hydraulic variable-speed power-transmission apparatus having pump and motor units incorporating the novel features of the present invention;

Fig. 2 is a part-sectional view on line 2—2 of Fig. 1, or on a corresponding line through the pump, showing the curved rocker-bearings at the ends of the piston-rods in tangential engagement with the flat faces on the reaction ring and illustrating the various angular positions of the piston-rods;

Fig. 3 is a view similar to Fig. 2 showing a modified form of construction of the reaction ring as having a cylindrical interior surface for tangential engagement by the rocker-bearings at the ends of the piston-rods;

Fig. 4 is a transverse sectional view taken generally on line 4—4 of Fig. 1 showing the coupling for connecting the motor shaft and reaction ring for rotation about eccentric axes;

Fig. 5 is a diagrammatic view illustrating the automatic adjustment of the center of the coupling resulting from manual adjustment of the eccentricity of the reaction ring with respect to the shaft;

Fig. 6 is a transverse sectional view on line 6—6 of Fig. 1 showing the ported valve-plate on the casing and illustrating the relative positions of the cooperating ports in the cylinder-block; and

Fig. 7 is an enlarged sectional view on line 7—7 of Fig. 1 showing the ball-and-socket connection of the piston-rod to its piston.

The pumps and motors commonly used in hydraulic variable-speed power-transmission apparatus comprise radial cylinders arranged in angular spaced relationship for rotation about a fixed axis and a reaction ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders. Pistons are provided in the cylinders and piston-rods extend between the pistons and the reaction ring. The cylinder-block and ring are rotated as a unit and due to the eccentricity of their axes the ring moves relatively of the cylinder-block during rotation through the same angular distance. Usually,

shoes are provided at the ends of the piston-rods which bear against the ring and slide thereon. With such a form of construction the shoes are subject to excessive wear and considerable energy is dissipated in the friction resulting from the sliding action of the shoes on the ring. It is preferable to positively couple the cylinder-block and reaction ring for rotation as a unit, but the usual types of couplings for connecting the members for rotation about eccentric axes have reciprocating parts which produce vibration, especially where heavy loads are transmitted at high speed. Furthermore, the cylinder-blocks of such radial pump or motor units are usually mounted to rotate on ported pintles which control the intake and exhaust of motive fluid to and from the cylinders. With motive fluid at pressures of the order of twelve-hundred pounds per square inch leakage is caused between the block and ported pintle, especially after the contacting parts become worn.

The present invention relates generally to radial pump or motor units for use in hydraulic variable-speed power-transmission apparatus having the usual radial cylinders and reaction ring, but provided with piston-rods adapted to rock on the ring to materially reduce friction and wear. For this purpose, each piston-rod is pivotally connected at one end to its piston and has a rigid rocker-bearing at its opposite end provided with a curved periphery engageable with the interior of the reaction ring tangentially thereof. During rotation of the cylinder-block and reaction ring about eccentric axes the curved peripheries of the rocker-bearings at the ends of the piston-rods will rock on the ring to compensate for the relative movement therebetween. The contacting surfaces of the rocker-bearings and the reaction ring may have any particular contour to give a piston-stroke of the desired characteristics, but preferably the ring is provided with flat faces arranged equidistant from its axis with one face opposite each cylinder and the periphery of the rocker-bearing of each piston-rod is curved to an arc concentric with its pivotal connection to the piston. With such an arrangement of contacting surfaces on the piston-rod and ring the line of tangential engagement is always alined with the axis of the cylinder in any angular position of the piston-rod.

The cylinder-block and reaction ring of the pump or motor unit are connected for rotation at the same angular velocity by means of a coupling comprising radial arms pivotally connected at their inner ends and having articulate sliding connections with the cylinder-block and ring. The arms of such a coupling will rotate about their pivotal connection as an axis and swing with respect to each other during rotation of the cylinder-block and reaction ring about eccentric axes. With such a coupling, however, the pivotal axis of the arms remains fixed for any particular adjustment of the eccentricity of the reaction ring with respect to the cylinder-block and moves automatically to a new position when the eccentricity of the parts is adjusted.

The cylinder-blocks of the pump and motor units are also provided with ports at one end which communicate with the radial cylinders and cooperate with the inlet and outlet ports in a valve-member in the casing. Each cylinder-block is provided with horizontal cylinders in its end opposite the ports which extend parallel to the axis of the block and communicate with the radial cylinders. Pistons in the horizontal cylinders are operated by the motive fluid in the radial cylinders and cooperate with a suitable abutment to hold the ported end of the cylinder-block engaged with the valve-member in the casing. With such a valving mechanism the horizontal cylinders can be so designed as to apply an axial thrust to the cylinder-blocks proportional to the pressure of the motive fluid but only slightly in excess of the force tending to separate the valving surfaces.

Fig. 1 of the drawings illustrates a hydraulic variable-speed power-transmission apparatus comprising an electric motor **2** having a multi-sectional casing **3** attached to its end-wall **4**. The casing **3** comprises spaced annular sections **5** and **6**, an intermediate annular section **7**, and a disk-like end-wall **8** which are held in assembled relationship by horizontal bolts **9** extending through the end-wall **8** and sections of the casing and screwed into the end-wall **4** of the electric motor **2**. The motor **2** and casing **3** have feet **10** for mounting the assembly, preferably on a tank **11** constituting a reservoir for the hydraulic motive fluid. The intermediate section **7** of the casing **3** is in the form of a diaphragm or septum **15** which divides the casing into separate compartments **16** and **17**. The septum **15** is formed at its center with an annular hub constituting a valve-annulus **18** having an axial bore **19**. The valve-annulus **18** is formed with arcuately-shaped cored valve-ports **22** and **23** extending axially therethrough, see Fig. 6, and its ends are finished to provide bearing-faces **20** and **21**. The valve-ports **22** and **23** may function either as suction or exhaust ports depending upon the direction in which the apparatus is operated and either port is adapted to be supplied with motive fluid from the reservoir **11** through a supply-line comprising a conduit **24** and a check-valve **25**, see Figs. 1 and 3. Each check-valve **25** is adapted to close automatically when the motive fluid in its corresponding port **22** or **23** is under pressure and to open when suction exists to make up for any fluid leakage which may have occurred during operation of the apparatus.

A hydraulic pump **26** is mounted in the compartment **16** and a hydraulic motor **27** is mounted in the compartment **17** of the casing **3**. The pump **26** comprises a composite shaft **28** journaled in an anti-friction bearing **29** in the bore **19** of the valve-annulus **18** and an anti-friction bearing **30** in the end-wall **4** of the electric motor **2**. The shaft **28** has an enlarged annular boss **31** adjacent the bearing **30** providing a radial shoulder **32** and a cylindrical opening or chamber **33**, see Figs. 1 and 4. A hollow stem or thimble **35** is attached to the end of the boss **31** on the shaft **28** by means of screws **36** inserted through its radial flange **34**, the stem forming an extension of the shaft **28** and being journaled in the anti-friction bearing **30** surrounding the end of the motor-shaft **37**. As shown in Fig. 1, the interior of the hollow stem or extension **35** of the shaft **28** is fluted for cooperation with the splines **38** on the motor-shaft **37** to connect the two shafts for rotation.

Mounted on the shaft **28** between the shoulder **32** and the valve-annulus **18** of the casing section **7** is a cylinder-block **42**, see Fig. 1, having a plurality of radial bores **43**, see Fig. 2. The cylinder-block **42** is connected to the shaft **28** for rotation therewith by means of a key **44**. A bronze valve-plate **45**, fixedly attached to the end of the cylinder-block **42** by brazing or other suitable means, is adapted to bear against the ported face **20**

of the valve-annulus 18 on the intermediate casing-section 7. Extending through the valve-plate 45 and cylinder-block 42 are a series of ports 46, see Fig. 2, each of which is adapted to communicate with a cylinder-bore 43 and cooperate with the ports 22 and 23 of the valve-annulus 18 as indicated in Fig. 6. It is to be understood that a port 46 is provided for each cylinder-bore 43 and the ports are positioned with respect to the axis of the shaft 28 so as to cause them to aline successively with the ports 22 and 23 in the valve-annulus 18 during rotation of the cylinder-block 42 relative thereto. One of the ports 22 and 23 in the valve-annulus 18 will function as an outlet from the plurality of cylinder-bores 43 while the other port functions as an inlet to the cylinder-bores depending upon the direction in which the electric motor 2 rotates, the pump operating equally as well in either direction of rotation.

In the end-face of the cylinder-block 42 opposite from the valve-plate 45 are a series of horizontal bores 47 having axes extending at right-angles to the axes of the radial cylinder-bores 43. Each horizontal bore 47 communicates with its corresponding radial cylinder-bore 43 by means of a small port 48. A piston 49 is provided in each horizontal bore 47 for operation by the pressure of the motive fluid acting through the port 48 leading from the corresponding radial cylinder-bore 43. The pistons 49 bear against the radial shoulder 32 on the shaft 28 to apply a predetermined axial thrust to the cylinder-block 42 which is proportional to and slightly in excess of the force applied by the pressure of the motive fluid tending to force the valve-plate 45 away from the fixed valve-annulus 18 on the casing-section 7.

Surrounding the cylinder-block 42 is a reaction ring 52 mounted to rotate in a carriage 53. The ring 52 is generally of annular form and channel-shape in cross-section. As herein shown the ring 52 comprises three annular sections connected together by a series of screws 54, see Fig. 1. Abutting the inner sides of the channel-shaped ring 52 and held against relative rotation by the bolts 54 are a pair of annular guide-plates 55 designed for a purpose as will appear later. An annulus or collar 56, attached to the side of the reaction ring 52 by means of screws 57, extends laterally therefrom or to the right as viewed in Fig. 1. The annulus or collar 56 is positioned so as to surround the boss 31 on the shaft 28.

The carriage 53 likewise is of annular form, see Fig. 2, and channel-shaped in cross-section to enclose the ring in nested relationship. The reaction ring 52 is mounted to rotate on anti-friction roller-bearings 58 and 59 positioned between the carriage and ring at opposite sides thereof, see Figs. 1 and 4. The carriage 53 is mounted to slide vertically in the casing-section 5 to adjust the eccentricity of the axis of the ring with respect to the axis of the shaft 28. For this purpose the carriage 53 has flat vertical sides 60 and 61 which slide on cooperating guide-members or ways 62 and 63 on the interior of the casing-section 5, see Fig. 2. Integral with or attached to the top of the carriage 53 is a screw-threaded stem 64 which projects upwardly through a suitable opening in the casing-section 5 and through alined holes in spaced bearings 65 and 66 mounted thereon. Positioned between the bearings 65 and 66 is a handwheel 67 having an internally-threaded hub 68 which cooperates with the threaded stem 64. By rotating the handwheel 67 the stem 64 may be moved axially in one direction or the other which, in turn, will move the carriage 53 vertically with respect to the casing-section 5 to adjust the eccentricity of the axis of the reaction ring 52 with respect to the axis of the shaft 28.

The hydraulic motor-unit 27 is of a construction substantially identical with that of the pump 26 but of opposite hand. For convenience of description the elements of the motor are designated by different reference characters but similar details of construction are indicated by the same characters as used in the description of the pump. The motor-unit comprises a shaft 72 journaled in an anti-friction bearing 73 in the bore 19 of the valve-annulus 18 with an axial extension 71 journaled in a ball-bearing 74 in the end-wall 8 of the casing 3. The shaft 72 has a boss 31 forming a shoulder 32 and a cylindrical chamber 33 at its end. The shaft-extension 71 has a radial flange fastened to the end of the boss 31 on the shaft 72 by screws 36 with its end projecting outwardly through the end-wall 8 of the casing 3 for connection with the apparatus to be driven. Mounted on the shaft 72 is a cylinder-block 78 having radial cylinder-bores 43 and horizontal bores 47 identical with those described with respect to the pump 26. The cylinder-block 78 is connected to the shaft 72 by means of a key 44 and the radial bores 43 are connected to the horizontal bores by means of ports 48. At its inner end the cylinder-block 78 has a valve-plate 45 brazed thereto and adapted to bear against the ported face 21 of the valve-annulus 18 on the casing-section 6. The cylinder-block 78 and valve-plate 45 also are provided with a series of laterally-extending ports 46, one for each cylinder-bore 43, arranged to cooperate with the ports 22 and 23 in the valve-annulus 18 in the manner previously described with respect to the pump.

Surrounding the cylinder-block 78 is a ring 80 mounted to rotate in a carriage 81. The ring 80 and carriage 81 are of a construction identical with that of the ring 52 and carriage 53 of the pump, being of channel-shape in cross-section and nested one within the other. The ring 80 is rotatable in roller-bearings 58 and 59 positioned between the ring and carriage at opposite sides thereof with annular guide-plates 55 and a laterally-extending annulus or collar 56 which surrounds the hub 31 of the shaft 72. The carriage 81 also has flat sides 60 and 61 which slide on guide-ways 62 and 63 on the interior of the casing-section 6. The carriage 81 is adjustable with respect to the cylinder-block 78 by means of a handwheel 67 having its hub 68 in threaded engagement with the screw-threads on a stem 64 extending from the carriage and cooperating with spaced bearings 65 and 66.

Mounted in each bore 43 of the cylinder-blocks 42 and 78 of the pump and motor units 26 and 27 is a flanged sleeve 85 which is fastened in place by brazing or welding it thereto, see Fig. 7. The sleeves 85 are of hardened steel or the like and constitute linings for the cylinders. A piston 86 mounted to reciprocate in each cylinder 43 has a close fit within the bore of the lining sleeve 85.

In accordance with the present invention the piston-rod for each piston 86 is adapted to rock on the reaction ring 52 or 80 during rotation of the cylinder-block 42 or 78 and ring 52 or 80 about eccentric axes. Each piston-rod 87 has a ball-joint at one end for connecting it to the piston and a rocker-bearing 89 at its opposite end provided with a curved face 90 for contact with

the interior of the ring 52 or 80 tangentially thereof, see Fig. 2. An integral spherical enlargement or ball 88 at the end of each piston-rod 87 is adapted to seat in a correspondingly-shaped semi-spherical socket 91 in its piston 86, being held in place by means of a ring 92 having a spherical cavity overlying a portion of the ball. The ring 92 is clamped in position on the piston 86 by means of a second ring 93 screwed into the skirt of the piston, see Fig. 7.

The curved face 90 of the rocker-bearing 89 at the outer end of each piston-rod 87 and the co-operating face on the interior of the reaction ring 52 or 80 may have any suitable contour to give the desired piston-stroke and pressure characteristics to the motive fluid. In the preferred form of construction illustrated in Figs. 1, 2, and 7 of the present drawings, the curved face 90 of each rocker-bearing 89 is of arcuate contour concentric to the pivotal axis of the piston-rod 87 at the center of the ball 88 and the reaction ring 52 or 80 has a flat contact face 94 normal to a radius of the ring and disposed opposite each cylinder 43. With such a construction and arrangement of the piston-rods 87 and reaction ring 52 or 80 the arcuate faces 90 of the rocker-bearings 89 will engage the flat faces 94 on the ring tangentially and the point of contact of each rocker-bearing will always aline with the axis of its cylinder in any angular position of the piston-rod, see the center line A—O in Fig. 2. In other words, the line of force from the pivotal axis of the piston-rod 87 to the point of tangential contact of the arcuate face 90 of each rocker-bearing 89 with the flat face 94 on the ring 52 or 80 will always coincide with a radius from the center of the cylinder-block 42 or 78.

To retain the piston-rods 87 in proper position while the pump and motor units 26 and 27 are idle the rocker-bearings 89 are provided with laterally-projecting pins 96 which engage in arcuate slots 97 in the sides of the annular guide-plates 55, previously referred to, at opposite sides of the rings 52 and 80. The slots 97 are of such shape as to hold the arcuate faces 90 of the rocker-bearings 89 in contacting engagement with the flat faces 94 of the rings 52 and 80 while permitting angular movement of the piston-rods 87 to the various positions illustrated in Fig. 2.

Fig. 3 shows a form of construction of the invention identical with that of Figs. 1 and 2 except as to the form of the contact faces on the ring 98 which are engaged by the arcuate peripheries 90 of the rocker-bearings 89. In this embodiment of the invention illustrated in Fig. 3 the interior of the ring 98 is of cylindrical contour while the arcuate periphery 90 of each rocker-bearing 89 is concentric with the pivotal axis of its piston-rod 87. With this form of construction the line of force from the pivotal axis of the piston-rod 87 to the point of tangential contact of the rocker-bearing 89 on the ring 98 will always coincide with a radius from the axis of the ring as shown by the line B—Y in Fig. 3. It will be obvious, therefore, that with the form of construction illustrated in Fig. 3 a side thrust on the pistons 86 is engendered, resulting in increased wear over that which will result from the use of the improved construction illustrated in Fig. 2. It is to be understood, however, that other modified forms of contact surfaces may be provided on the rocker-bearing 89 of the piston-rods 87 and ring 52 or 80 to give any desired characteristics. For example, the contact faces may be so formed as to give a constant flow-characteristic to the motive fluid whereby to avoid impulses caused by the usual harmonic motion of the piston.

The present invention also contemplates the use of couplings of novel construction for connecting the shaft 28 of the pump 26 and the shaft 72 of the motor 27 to their respective reaction rings 52 and 80. Each of the couplings comprises a plurality of radial rods or arms 101, 102 and 103, see Figs. 1 and 4, pivotally connected at their inner ends and having articulated sliding connections with the boss 31 and annulus or colar 56 of the shaft 28 or 72 and ring 52 or 80. As illustrated in Fig. 4, the arm 101 has a bearing-block 104 at its inner end while the other two arms 102 and 103 have bifurcated ends or forks 105 and 106, the fork 105 straddling the block 104 and the fork 106 straddling the end 105. The inner ends of the arms 101, 102 and 103 are located in the cylindrical chamber 33 in the shaft 28 or 72 and pivotally connected by a single pin 107 extending through the bifurcated ends 105 and 106 and the bearing-block 104.

To provide for an articulated sliding connection of the arms 101, 102 and 103 with the shafts 28 and 72 and rings 52 and 80 the bosses 31 of the shafts are each provided with a plurality of bores 109 in which pins 111 are journaled for rocking movement and the collars 56 of the rings are each provided with a plurality of bores 110 in which similar pins 112 are journaled. The pins 111 and 112 are provided with transverse holes through which the arms 101, 102 and 103 extend and the sides of the bores 109 and 110 are beveled to provide clearance to allow the arms to rock about the axes of the pins. Although the couplings are shown in Fig. 4 of the drawings as comprising three arms 101, 102 and 103 with the pins 111 and 112 arranged 120° apart around the boss 31 and collar 56, it is to be understood that the couplings may have a greater number of arms if desired. During rotation of the shaft 28 or 72 its motion is transmitted by the arms 101, 102 and 103 of the coupling to rotate the ring 52 or 80, the arms being caused to rock or swing relative to each other during this rotation with the pins 111 and 112 rocking to permit this relative movement of the arms.

The construction and arrangement of the present improved couplings eliminates the vibration that is present in the usual type of coupling employed to connect parts for rotation about eccentric axes. The elimination of vibration is due to the fact that the axis of the pivot-pin 107 of each coupling remains stationary during rotation of the coupling at any particular adjustment of the eccentricity of the reaction ring 52 or 80 with respect to the shaft 28 or 72. However, when the eccentricity of the reaction ring 52 or 80 is adjusted with respect to the axis of the shaft 28 or 72 the axis of the pivot-pin 107 will be moved in the opposite direction from that of the axis of the shaft as indicated diagrammatically in Fig. 5. In Fig. 5 the full lines indicate the relationship of the arms 101, 102 and 103 of the coupling for a certain adjustment of the eccentricity of the reaction ring 52 or 80 with respect to the shaft 28 or 72. It will be noted that the axis X of the pivot-pin 107 is located below the axis O of the shaft 28 or 72 a distance equal to the eccentricity of the axis Y of the ring 52 or 80 above the axis of the shaft. Also in Fig. 5, the dash-lines indicate the relationship of the arms 101, 102 and

103 and the position of the ring 52 or 80 at a point when the axis Y of the ring is adjusted toward the axis O of the shaft 28 or 72 to the position indicated by the reference character Y". When the reaction ring 52 or 80 is adjusted in the manner last described the axis X of the pivot-pin 107 will be shifted automatically toward the axis O of the shaft 28 or 72 to the position indicated by the reference character X'. It will be noted that the positions inicated at X' and Y' are always equi-distant from the axis O of the shaft 28 or 72 but at opposite sides thereof. After the eccentricity has been once adjusted, however, the axis X of the pin 107 will remain fixed throughout the operation of the pump 26 or motor 27.

To provide for drainage of any motive fluid which may escape from the cylinders 43 in the cylinder-blocks 42 and 78 the shafts 28 and 72 have small axial passages 120, see Fig. 1, which communicate with the cylindrical chambers 33 in the shafts and the bosses 31 have small radial passages 121, see Fig. 4, communicating with the compartments 16 and 17 of the casing 3. Beside providing for the drainage of escaping motive fluid the passages 120 and 121 provide for circulating the motive fluid, preferably oil, to lubricate the pivot-pins 107, arms 101, 102 and 103 and rocking pins 111 and 112 of the couplings. The heads of the pistons 86 also are provided with axial passages 122, see Fig. 7, for supplying motive fluid to lubricate the balls 88 on the piston-rods 87 as they rock in the sockets 91 in the pistons. One embodiment of the invention having been described in detail the mode of operation of the apparatus is explained as follows:

For the purpose of the present description let it be assumed that the cylinders 43 and connecting passages in the pump 26 and hydraulic motor 27 are filled with motive fluid and that the electric motor 2 is energized to turn in clockwise direction as viewed in Fig. 2. Rotation of the motor-shaft 37 thus will rotate the shaft 28 and cylinder-block 42 of the pump 26 in the same direction. The rotation of the shaft 28 will be transmitted to the reaction ring 52 by the arms 101, 102 and 103 which are slidably connected to the rockable pins 111 and 112 in the boss 31 of the shaft and the collar 56 of the ring, see Fig. 4, so that the shaft and ring will rotate at the same angular velocity. During this rotation of the cylinder-block 42 and reaction ring 52 about eccentric axes the arms 101, 102 and 103 of the coupling will rock with respect to each other and slide axially in the pins 111 and 112 in the hub 31 of the shaft 28 and the collar 56 of the ring 52. The oppositely-inclined bevels at the sides of the openings 109 in the boss 31 and the openings 110 in the collar 56, in which the pins 111 and 112 are journaled, will permit the arms to rock angularly and the transverse holes in the pins will permit the arms to slide axially.

Due to the eccentricity of the axis of the ring 52 with respect to the axis of the shaft 28 the distance between the periphery of the cylinder-block and the interior face of the reaction ring will increase progressively on one side of the pump from minimum to maximum while the distance between the periphery of the cylinder-block and the interior face of the ring at the opposite side of the pump will decrease gradually from maximum to minimum. The pistons 86 in the cylinders 43 thus will be moved successively through a suction stroke during one-half of a revolution to draw motive fluid into the cylinders through the intake port 22 in the valve-annulus 18 and the ports 46 in the cylinder-block 42. During the second half-revolution the pistons 86 will be moved inwardly in the cylinders 43 successively to deliver the motive fluid under pressure through the ports 46 in the cylinder-block 42 and the port 23 in the valve-annulus 18. In other words, the pistons 86 will be moved through a suction stroke at the left-hand side of the pump as viewed in Fig. 2 and moved through a pumping stroke at the right-hand side of the pump. By reference to Fig. 6 it will be noted that the ports 46 in the cylinder-block 42 for three of the cylinders 43 are alined with the intake port 22 in the valve-plate 18 while three other ports 46 are alined with the exhaust port 23, a seventh port being positioned between the intake and exhaust ports.

Corresponding points on the shaft 28 and ring 52 will coincide with a vertical line through the axes O and Y of the shaft and ring below the shaft, see Fig. 5. During rotation of the shaft 28 and ring 52 at the same angular velocity through a quarter-revolution the point on the ring is gradually displaced vertically in advance of the corresponding point on the shaft due to the eccentricity of the axes O and Y of the shaft and ring. At the end of a quarter-revolution the displacement of the corresponding points on the shaft 28 and ring 52 will be equal to the eccentricity of the axes O and Y of the shaft and ring. During the second quarter-revolution the displacement of the corresponding points on the shaft 28 and ring 52 will diminish gradually until the points again coincide with a vertical line through the axes O and Y. During the third-quarter revolution the point on the shaft 28 is displaced in advance of the corresponding point on the ring 52 until the displacement reaches a maximum corresponding to the eccentricity of the axes O and Y. During the fourth quarter-revolution the displacement gradually diminishes until the corresponding points on the shaft 28 and ring 52 again coincide with the vertical line. Due to the gradually increasing and diminishing displacement between the ring 52 and cylinder-block 42 during their rotation at the same angular velocity a relative movement will take place between the contact faces of the piston-rods 87 and the interior of the ring 52. To compensate for such relative movement of the shaft 28 and ring 52 the arcuate peripheries 90 of the rocker-bearings 89 at the ends of the piston-rods 87 will rock on the flat faces 94 on the interior of the ring 52.

Furthermore, due to the arcuate contour 90 of the rocker-bearings 89 on the piston-rods 87 they will contact the flat faces 94 on the ring 52 tangentially and the point of tangential contact of each piston-rod invariably will aline with the axis of its related cylinder 43 in any angular position of the piston-rod, note the direction of force indicated by the line A—O in Fig. 2. As a result, the force for moving the pistons 86 in the cylinders 43 always will be applied in line with the axis of the cylinders to prevent cramping of the pistons; and further to reduce the wear on the pistons and cylinders to a minimum. The arcuate faces 90 of the rocker-bearings 89 on the piston-rods 87 invariably will be maintained in contact with the flat faces 94 on the ring 52 by the engagement of the laterally projecting pins 96 in the slots 97 in the guide-plates 55. The curved slots 97 are of a contour, however, such as to per-

mit rocking movement of the piston-rods 87 to the various angular positions shown in Fig. 2.

The motive fluid under pressure in the cylinders 43 at one side of the pump 26 will be caused to flow through the small ports 48 into the horizontal cylinder-bores 47 to operate the pistons 49. Consequently the pistons 49 will be forced against the radial shoulder 32 on the boss 31 of the shaft 28 to apply a predetermined axial thrust proportional to and slightly in excess of the force produced by the motive fluid tending to separate the valve-plate 45 from the fixed valve-annulus 18. As a result, the valve-plate 45 of the cylinder-block will be maintained in firm engagement with the valve-annulus 18, but with a force only slightly in excess of that required to prevent leakage whereby to maintain the friction between the moving parts at a minimum.

The motive fluid delivered under pressure from the pump 26 is conducted through the port 23 in the fixed valve-annulus 18 and the ports 46 in the cylinder-block 78 at the right-hand side of the hydraulic motor-unit 27, as viewed in Fig. 2, and into the cylinders 43 thereof. The introduction of the motive fluid into the cylinders 43 of the motor 27 will apply pressure to the pistons 86 to transmit force through the piston-rods 87 to the reaction ring 80. Due to the eccentricity of the axis of the cylinder-block 78 and ring 80 a force-couple is produced which will cause rotation of the ring 80 in counterclockwise direction. The connection of the hub 31 of the shaft 72 with the collar 56 of the ring 80 by means of the arms 101, 102 and 103 of the coupling will cause the shaft 72 and cylinder-block 87 keyed thereto to rotate in unison with the ring 80. At the opposite or left-hand side of the hydraulic motor 27 the ports 46 communicate with the port 22 in the valve-annulus 18 to exhaust the motive fluid from the cylinders 43 to cause it to flow back to the pump 26.

During the rotation of the shaft 72 and the reaction ring 80 the rocker-bearings 89 on the piston-rods 87 will rock on the ring in the manner previously explained with respect to the pump 26. The motive fluid in the cylinders 43 of the cylinder-block 78 will be transmitted through the small ports 48 to operate the pistons 49 which bear against the annular shoulder 32 on the boss 31 of the shaft 72 to apply a predetermined axial thrust to the cylinder-block 78 to maintain the valve-plate 45 engaged with the face 21 of the fixed valve-member 18. As in the case of the pump 26, the valve-plate 45 of the cylinder-block 78 of the motor 27 is held in engagement with the face 21 of the fixed valve-annulus 18 with a force proportional to the pressure of the motive fluid, but only slightly in excess of that required to hold the valve-members engaged.

The variable-speed power-transmission apparatus will continue to operate in the manner indicated, the pump 26 supplying motive fluid under pressure to the hydraulic motor 27 and the ports 46 in both of the cylinder-blocks 42 and 78 cooperating successively with the ports 22 and 23 and the fixed valve-annulus 18. The motive fluid exhausting from the motor 27 will flow through the port 22 which constitutes the intake for the pump 26. Any motive fluid escaping from the system due to leakage between the pistons and cylinders will be compensated for by the flow from the tank 11 through the check-valve 25 and conduit 24 connected to the port 22 in the valve-annulus 18.

The relative speeds of the pump and motor are directly proportional to the volumetric displacement of the cylinders 43 in the cylinder-blocks 42 and 78. For example, if the volumetric displacement of the cylinders 43 in the cylinder-block 78 of the hydraulic motor 27 is greater than the volumetric displacement of the cylinders 43 in the cylinder-block 42 of the pump 26, then the motor 27 will rotate at a slower rate of speed than that of the pump 26. On the other hand, if the volumetric displacement of the cylinders 43 of the hydraulic motor 27 is less than the volumetric displacement of the cylinder 43 of the pump 26 then the motor will rotate at a higher rate of speed than that of the pump. Usually, the volumetric displacement of the pump is regulated for a particular condition by adjusting the eccentricity of the ring 52 with respect to the cylinder-block 42. For this purpose the hand-wheel 67 may be rotated to slide the threaded stem 64 axially and move the carriage 53 vertically. The axis of the reaction ring 52 rotatably mounted on the carriage 53 thus can be adjusted with respect to the axis of the shaft 28. With the eccentricity of the pump 26 adjusted for a particular condition the eccentricity of the reaction ring 80 of the hydraulic motor 27 may be adjusted with respect to its cylinder-block 78 to produce any desired variation in the speed of the motor within certain prescribed limits.

It will now be observed from the foregoing specification that the present invention provides a hydraulic variably-speed power-transmission apparatus having pump and motor units with piston-rods adapted to rock on the reaction rings to reduce friction and wear. It also will be observed that the invention provides a novel form of coupling for connecting the cylinders and reaction ring of the pump or motor unit for rotation at the same angular velocity about eccentric axes. It will be observed still further that the present invention provides a novel form of valving mechanism in which the valve-surfaces are held in engagement with a predetermined axial force proportional to the pressure of the motor fluid but only slightly in excess of that required to maintain the valve surfaces engaged.

While a preferred form of apparatus incorporating the novel features of the present invention and a single variation in the form of the contact surfaces on the piston-rods and reaction ring are herein shown and described by way of illustration, it is to be understood that other modifications may be made in the form of the contact faces on the piston-rod and reaction ring and in the construction and arrangement of the parts of the apparatus without departing from the spirit or scope of the invention. Therefore, without limiting myself in this respect, I claim:

1. In a pump or motor unit, a rotor comprising radial cylinders arranged in angular relationship and mounted for rotation about a fixed axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders, means for connecting the ring for rotation with the cylinders, and a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact and rockable thereon without substantial sliding movement.

2. In a pump or motor unit, a shaft, a rotor on said shaft comprising radial cylinders arranged in angular spaced relationship for rotation about the axis of the shaft, pistons in said

cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of the shaft, means for connecting the ring for rotation with the cylinders, and a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact, said rocker-bearing being curved in an arc concentric to the pivotal axis of the piston-rod to adapt it to the rock on the ring without substantial sliding movement.

3. In a pump or motor unit, a shaft, a rotor on said shaft comprising radial cylinders arranged in angular relationship for rotation about the axis of the shaft, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of the shaft, means for connecting the ring for rotation with the cylinders, means for relatively shifting the ring and rotor to adjust the eccentricity of the axes of rotation, and a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact, said rocker-bearing being adapted to rock on the ring without substantial sliding movement to compensate for the relative movement of the cylinder and ring during their rotation about eccentric axes.

4. In a pump or motor unit, a shaft, a rotor on said shaft comprising radial cylinders arranged in angular relationship for rotation about the axis of the shaft, pistons in said cylinders, each piston having a spherical socket, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders, means for connecting the ring for rotation with the cylinders, and a piston-rod for each piston having a ball at one end rockable in the socket in its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact, said rocker-bearing being adapted to rock on the ring without substantial sliding movement to compensate for the relative movement of the cylinder and ring during their rotation about eccentric axes.

5. In a pump or motor unit, a shaft, a rotor on said shaft comprising radial cylinders arranged in angular relationship for rotation about the axis of the shaft, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of the shaft, means for connecting the ring for rotation with the cylinders, a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact and rockable thereon without substantial sliding movement to compensate for the relative movement of the cylinder and ring during their rotation about eccentric axes, and means for connecting the rocker-bearing of each piston-rod to the ring to maintain it in engagement with the ring while permitting its rocking movement relative thereto.

6. In a pump or motor unit, radial cylinders arranged in angular spaced relationship for rotation about a common axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders, means for connecting the ring for rotation with the cylinders, said ring having a flat interior face opposite each cylinder, and a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging one of the flat faces on the ring tangentially on a single line of contact, each rocker-bearing being adapted to rock on one of the flat faces of the ring without substantial sliding movement to compensate for the relative movement of the cylinder and ring during their rotation about eccentric axes.

7. In a pump or motor unit, radial cylinders arranged in angular spaced relationship for rotation about a common axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders, means for connecting the ring for rotation with the cylinders, said ring having a flat interior face opposite each cylinder, and a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging one of the flat faces on the ring tangentially on a single line of contact and rockable thereon without substantial sliding movement, each rocker-bearing having its face curved in an arc concentric to the pivotal axis of its piston-rod whereby to cause said rocker-bearing to engage the flat face on the ring in a plane coincident with the axis of the cylinder at any angular position of the piston-rod.

8. In a pump or motor unit, a shaft, radial cylinders arranged in angular spaced relationship for rotation about the axis of the shaft, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders, means for connecting the ring for rotation with the cylinders, said ring having a flat face opposite each cylinder, a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engageable with one of the flat faces on the ring and rockable thereon to compensate for the relative movement of the cylinder and ring during their rotation about eccentric axes, said rocker-bearing having an arcuate face curved in an arc concentric to the pivotal axis of the piston-rod whereby to cause the rocker-bearing to engage the flat face on the ring in a plane coincident with the axis of the cylinder in any angular position of the piston-rod, and means for maintaining the arcuate face of each rocker-bearing in engagement with the ring while permitting its rocking movement relative thereto.

9. In a pump or motor unit, a rotor comprising radial cylinders arranged in angular relationship for rotation about a common axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the cylinders, a piston-rod for each piston extending between its piston and the ring, and a coupling having a plurality of radial arms for connecting the ring for rotation with the rotor, said arms of the coupling being pivotally connected to each other at their inner ends on a common axis and having articulated connections with the rotor and ring.

10. In a pump or motor unit, a rotor comprising radial cylinders arranged in angular relationship for rotation about a common axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation thereof, means for relatively shifting the ring and rotor to adjust the eccentricity of their axes of rotation, a piston-rod for each piston extending between its piston and the ring, and a coupling having a plurality of radial arms for connecting the ring for rotation with the rotor and permitting adjustment of their axes, said radial arms

of the coupling being pivotally connected to each other at their inner ends on a common axes and having articulated connections with the rotor and ring.

11. In a pump or motor unit, a shaft having a hollow boss forming a rim, pins mounted in the rim to rock on axes parallel to the axis of the shaft, a rotor comprising radial cylinders arranged in angular relationship on said shaft for rotation therewith, pistons in said cylinders, a ring surrounding said cylinders with its axis eccentric to the axis of the shaft, pins mounted in the ring to rock on axes parallel to the axis of the ring, said pins on the shaft and ring being spaced in the same angular relationship, a piston-rod for each piston extending between its piston and the ring, and a coupling having a plurality of arms extending outwardly through the rockable pins in the shaft and ring to connect the latter for rotation as a unit, the inner ends of said arms being pivotally connected to each other on a common axis to permit relative swinging movement thereof.

12. In a pump or motor unit, a casing having a fixed valve-element with inlet and outlet ports, a cylinder-block mounted to rotate and slide axially in the casing and having radial cylinders therein for receiving motive fluid, said cylinder-block having an end-face in a plane parallel to the axes of the cylinders for engagement with the valve-element in the casing, said end-face of the cylinder-block having ports communicating with the cylinders and adapted to cooperate with the inlet and outlet ports in the valve-element, a ring surrounding the cylinders, pistons in the cylinders, piston-rods extending between the pistons and ring, and expansible means operated by the pressure of the motive fluid in the cylinders for applying an axial force to the cylinder-block to maintain its end-face engaged with the valve-element of the casing.

13. In a pump or motor unit, a casing having a fixed valve-element with inlet and outlet ports, a cylinder-block mounted to rotate and slide axially in the casing and having radial cylinders for receiving motive fluid, said cylinder-block having an end-face for engagement with the valve-element and having ports communicating with the cylinders adapted to cooperate with the inlet and outlet ports of the valve-element, the opposite end of the cylinder-block having axial cylinders communicating with the radial cylinders, a ring surrounding the radial cylinders, pistons in the radial cylinders, piston-rods extending between the pistons and ring, and pistons in the axial cylinders in the end of the cylinder-block arranged to be operated by the motive fluid in the radial cylinders for applying an axial force to the cylinder-block to maintain its end-face engaged with the valve-element of the casing.

14. In a pump or motor unit, a casing having a fixed valve-element with inlet and outlet ports, a shaft mounted to rotate in the casing and having a radial abutment thereon, a cylinder-block keyed to the shaft and slidable axially thereon, said cylinder-block having radial cylinders for receiving motive fluid and axial cylinders in one end thereof communicating with the radial cylinders, the opposite end-face of the cylinder-block being engageable with the fixed valve-element and having ports communicating with the radial cylinders adapted to cooperate with the inlet and outlet ports in the valve-element, a ring surrounding the radial cylinders, pistons in the radial cylinders, piston-rods extending between the pistons and ring, and pistons in the axial cylinders in the cylinder-block engageable with the radial abutment on the shaft, said pistons in the axial cylinders being operated by the motive fluid in the radial cylinders for applying an axial thrust to the cylinder-block to maintain its end-face engaged with the valve-element of the casing.

15. In a pump or motor unit, a casing having a fixed valve-element with inlet and outlet ports, a shaft mounted to rotate in the casing and having a radial abutment thereon, a cylinder-block keyed to the shaft and slidable axially thereof, said cylinder-block having radial cylinders for receiving motive fluid and axial cylinders at one end thereof communicating with the radial cylinders, the opposite end-face of the cylinder-block being engageable with the fixed valve-element and having ports communicating with the radial cylinders adapted to cooperate with the inlet and outlet ports in the valve-element, a ring surrounding the radial cylinders, pistons in the radial cylinders, a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engageable with the ring tangentially thereof, radial arms pivotally connected at their inner ends and having articulated connections with the shaft and ring, and pistons in the axial cylinders in the cylinder-block engageable with the radial abutment on the shaft, said pistons in the axial cylinders being operated by the motive fluid in the radial cylinders for applying an axial thrust to the cylinder-block to hold its end-face engaged with the valve-element of the frame.

16. In a device of the type indicated, a casing having a central valve-element, said valve-element having arcuate inlet and outlet ports extending therethrough, a pump unit in the casing located at one side of the valve-element and having a cylinder-block mounted for rotation and axial sliding movement, a motor unit mounted in the casing at the opposite side of the valve-element from the pump unit and having a cylinder-block mounted for rotation and axial sliding movement, said cylinder-blocks of the pump and motor units each having radial cylinders and axial cylinders communicating with the radial cylinders, the adjacent end-faces of the cylinder-blocks being engageable with the opposite sides of the fixed valve-element and having ports communicating with the radial cylinders, said ports being adapted to cooperate with the inlet and outlet ports in the valve-plate, rings surrounding the cylinder-blocks, pistons in the radial cylinders, piston-rods extending between the pistons and rings, and pistons in the axial cylinders in the cylinder-blocks, said pistons in the axial cylinders of the cylinder-blocks being operated by the motive fluid in the radial cylinders and cooperating with abutments for applying axial forces on the cylinder-blocks to hold their adjacent end-faces engaged with the opposite sides of the valve-element.

17. In a pump or motor unit, a rotor comprising radial cylinders arranged in angular relationship for rotation about a fixed axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of the rotor, means for connecting the ring for rotation with the cylinders, a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact and rockable thereon without substantial sliding

movement, and pin-and-slot connections between the rocker-bearings and the ring for maintaining said bearings in engagement with the ring while permitting their rocking movement relative thereto.

18. In a pump or motor unit, a rotor comprising radial cylinders arranged in angular relationship and mounted for rotation about a fixed axis, pistons in said cylinders, a ring surrounding the cylinders with its axis eccentric to the axis of rotation of the rotor, means for connecting the ring for rotation with the cylinders, a piston-rod for each piston having one end pivotally connected to its piston and a curved rocker-bearing at its opposite end engaging the ring tangentially on a single line of contact and rockable thereon without substantial sliding movement, said ring provided with slots, and pins on the rocker-bearings of the piston-rods engaging the slots in the ring to prevent disengagement of said bearings from the ring while permitting them to rock relatively of the ring.

CHRISTIAN E. GROSSER.