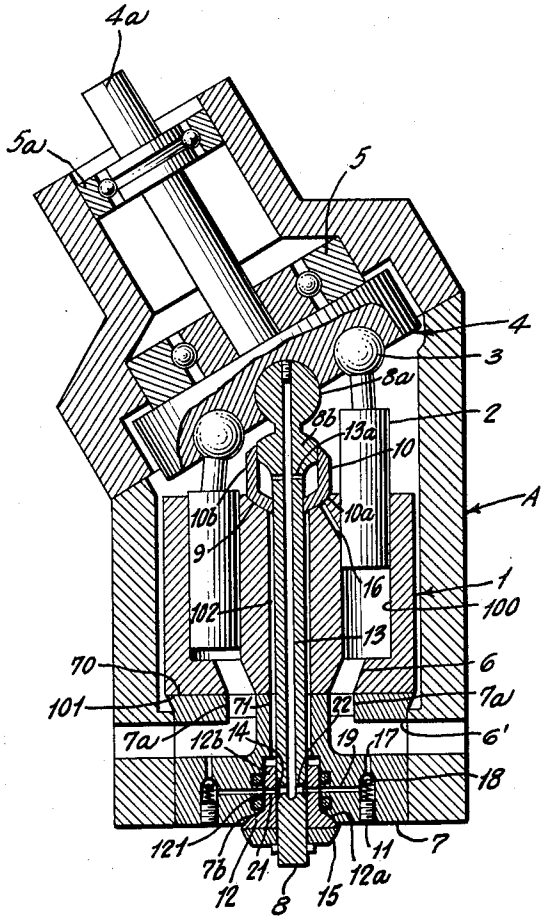
June 15, 1965 J. U. THOMA 3,188,972

AXIAL PISTON HYDRAULIC UNIT

Filed March 4, 1963 3 Sheets-Sheet 1

Fig. 1.



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AXIAL PISTON HYDRAULIC UNIT

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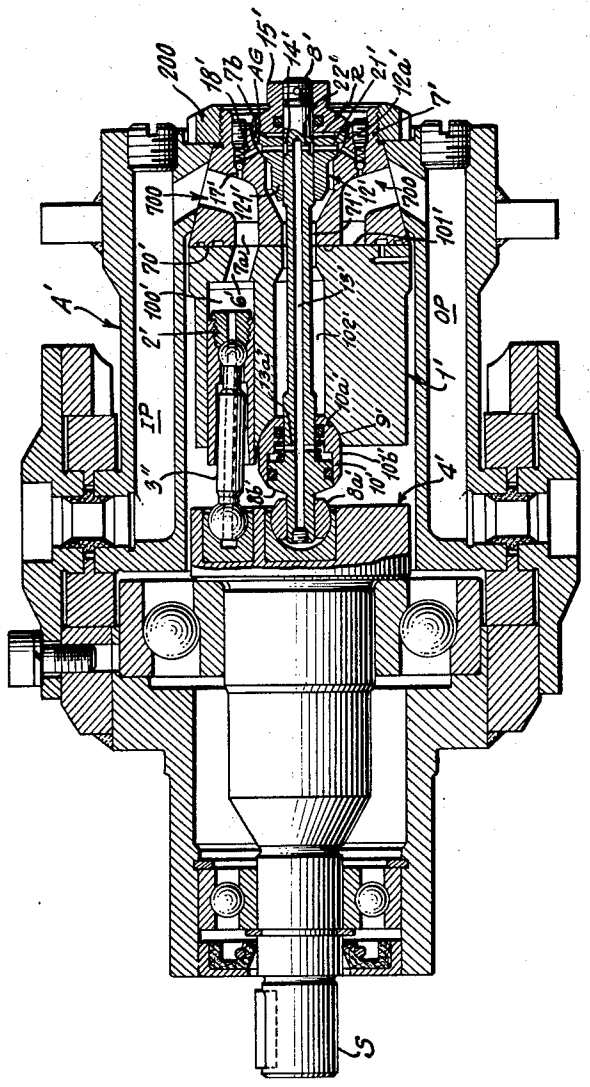


Fig. 2.

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June 15, 1965 J. U. THOMA 3,188,972

AXIAL PISTON HYDRAULIC UNIT

Filed March 4, 1963 3 Sheets-Sheet 3

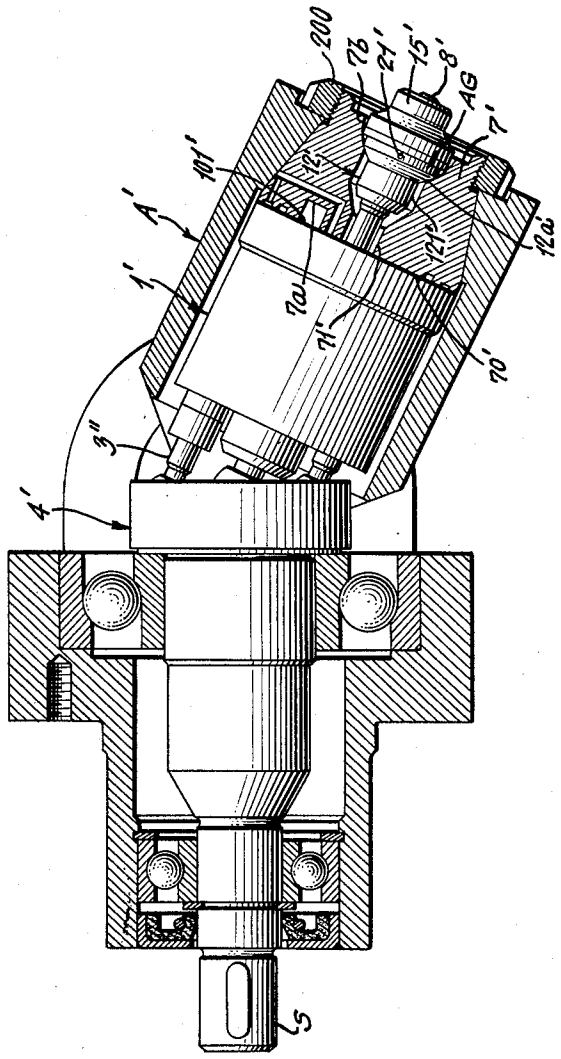


Fig. 3.

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United States Patent Office 3,188,972 Patented June 15, 1965

3,188,972

AXIAL PISTON HYDRAULIC UNIT

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Filed Mar. 4, 1963, Ser. No. 262,782
3 Claims. (Cl. 103—162)

The present invention relates broadly to the art of pumps or motors, more particularly, those referred to as axial piston hydraulic units.

Specifically, this invention is directed to a pump or motor of the type including a cylinder block provided with substantially parallel, piston-accommodating bores, a casing within which the block is mounted for rotation, pistons within each bore, a driving means mounted for rotation about an axis at an angle to the axis of the cylinder block and operably connected to the pistons whereby rotation of the driving means reciprocates the pistons and rotates the cylinder block with the casing. The unit further includes a valve plate within the casing engaging the base of the cylinder block and having suitably shaped admission and delivery ports adapted to register with ports in the cylinder block that communicate with the bores therein upon relative rotation of the cylinder block and valve plate.

The present invention is further related to axial piston hydraulic units of the type set forth in my prior filed application, Serial No. 828,803, filed July 22, 1959 and entitled "Axial Piston Hydraulic Units" now Patent No. 3,079,870 dated March 5, 1963.

In general, therefore, the invention of this application is applicable to hydraulic units as disclosed in Thoma U.S. Patent No. 2,155,455, dated April 25, 1939, and Vickers U.S. Patent No. 2,284,109, dated May 26, 1942.

In such devices, it is desirable that the cylinder carrier, which may be in the form of a cylinder block as shown in said mentioned patents, is constantly pressed into engagement with the valve plate. It is, of course, important that the forces pressing the cylinder block against the valve plate be so distributed that edge pressure is avoided, since such edge pressure will cause excessive pressure, wear and heating near the edge of the cylinder block. Such edge pressure does not occur when the cylinder ports and valve ports (such as 50 and 48, respectively, in the Vickers patent), are located in line with the center of the cylinder area. However, if these ports are located inwardly from the center of the cylinders as the ports 46 in FIG. 2 of Thoma United States Patent No. 2,155,455, such edge pressure will result in heating and wear at extremely high speeds and pressures unless appropriate steps are taken to overcome this difficulty. One way to accomplish this is by the use of a construction such as shown in Hans Thoma Canadian Patent No. 544,157, dated July 30, 1957. In said patent, the valve plate is given a convex shape so that the forces resulting from the oil under pressure in the cylinder act along a line at right angles to the valve plate surface rather than along two spaced lines forming a force couple which will be the case if a flat valve plate is used as in the Thoma United States patent mentioned.

There are, however, important manufacturing advantages which make the use of a planar valve plate surface advisable. It is, therefore, an object of the present invention to provide in such a hydraulic unit, having a plane or planar valve plate surface and having cylinder ports arranged inwardly of the cylinder axes, means for applying axial forces between the cylinder carrier and the valve plate so applied as to overcome any edge pressure therebetween.

Another object is to provide a central pivot pin, carried by the valve plate of such a unit, whether of the type having a fixed or a variable cylinder inclination, which

pin serves as an axis upon which the cylinder carrier may rotate and which pin also is supported through a universal joint connection in the driving flange to which the pistons are connected, and which central pivot also serves to apply longitudinal forces acting to force the cylinder carrier onto the valve plate.

Another object of the invention is to accomplish this result by means of a balancing piston operating in a cylinder, said piston and cylinder being located outwardly of the cylinder block and bearing against a seat or shoulder on the cylinder block and serving, when subjected to oil pressure, to force the cylinder block onto the valve plate.

Another object of the invention is to provide such a construction in which the central pin rotates with the cylinder block so as to eliminate relative rotative movement therebetween, and to reduce relative rotative movement between the central pin and the driving flange to a minimum. In that connection, it is also an object to provide a suitable thrust bearing between the central pin and the valve plate carrier to provide for relative rotative movement therebetween.

In such construction, the distribution or valve surfaces which are under pressure are designed a little smaller than the surfaces of the working pistons under pressure. Unfortunately, this leads to relatively small valve areas, and therefore to narrow valve ports.

Another object of the present invention is to provide a compact construction which at the same time allows of relatively large valve ports and provides an accurate kinematical guiding of the cylinder block.

Another object is to provide such a unit in which the central pivot is provided with a balancing cylinder and piston outward of the cylinder block and adjacent to the piston driving flange which transmit through a suitable abutment longitudinal forces from the central pivot to the cylinder block, which construction permits making the valve ports of the working cylinders (and the kidney-shaped intake and delivery ports of the valve plate) relatively large, without incurring the danger of lifting the self-sealing cylinder block from the valve plate.

It is another and important object of this invention to provide a hydraulic unit or arrangement of the type referred to above, in which the pivot pin, at least in a portion thereof passing through the cylinder block and valve plate, has less diameter than the diameter of the bores through the cylinder block and valve plate, the balancing cylinder includes a base having a spherical surface engaging with a spherical seat on the cylinder block, the valve plate has a spherical seat at a portion remote from the cylinder block, a bushing surrounds the central pin and has a spherical surface engaging with the seat on the valve plate and a thrust washer or means is secured to the pin and in engagement with the bushing, whereby the arrangement accommodates minute angular deviations between the pivot pin and the cylinder block, or between the pivot pin and the valve plate without disturbing the intimate contact between the base of the cylinder block and the facing surface of the valve plate.

It is a further and more important object to provide a hydraulic unit of the type including arrangements set forth in the immediately preceding paragraph, and in which an improved lubricating system is provided by means of ports and grooves establishing connection or flow of oil under pressure between the ports in the valve plate that connects with the cylinder, and the bearing surface between the bushing and valve plate, as well as between the facing surfaces of the bushing and thrust washer.

Further and more specific objects and advantages will be apparent from the following description taken in connection with the accompanying drawing, in which:

FIG. 1 is a longitudinal sectional view of an axial piston unit as shown in my prior application, Serial No. 828,803;

FIG. 2 is a view similar to FIG. 1, specifically illustrating the improved lubricating system of the invention; and,

FIG. 3 is a view partly in vertical section and partly in elevation, illustrating a casing and cylinder block in angular relation to the driving flange.

In the drawings, FIG. 1 illustrates the axial piston unit as including a cylinder block **1**, provided with working cylinders each containing a working piston **2**, each of which pistons is connected in known manner, as by ball-ended connecting rods **3** to the driving flange **4**, whose axis of rotation is inclined to the axis of rotation of the cylinder block. The driving flange **4** and the shaft **4***a* attached thereto are mounted in ball bearings **5** and **5***a*. The intake and delivery of the fluid is effected by the usual cylinder ports **6** passing over the usual kidney or segmentally shaped entry, and delivery ports **7***a* formed in the valve plate **7**. It should be noted that the valve plate **7** is drawn revolved about 90 degrees about its axis to show the valve ports **7***a*.

A central pivot pin **8** is journalled in the valve plate **7** at its lower end, and also may be journalled in the driving flange **4** by means of the ball joint **8***a*. Said central pivot **8** guides the cylinder block radially through the spherical abutment surface **9** on the cylinder block being engaged by a mating spherical external surface **10***a* on the lower end or base of the cup-shaped balancing cylinder **10** within which slides the piston **8***b*, shown formed as an enlarged portion of the central pivot pin **8**. Longitudinal forces are therefore transmitted to the cylinder block **1** through downward action of the balancing cylinder **10** acting on abutment or seat **9**. The reaction forces are transmitted through tension in central pivot pin **8**. These forces are proportional to the difference in cross-sectional area between the central pivot pin **8** and the enlarged portion or part **8***b*, the effect being that of a differential piston. These additional longitudinal forces act to press the cylinder block **1** against the valve plate **7**, thus making it possible to design the cylinder ports **6** reasonably large, without danger of lifting the cylinder block **1** away from the valve plate.

The balancing cylinder **10** may be fed by high pressure oil which is conducted from the main pressure conduits via the check valves **18** held in place by screws **11** into the longitudinal oil accommodating bore **13** in the central pivot **8**, and from there by small radial bores or ports **13***a* into the balancing cylinder **10**. The longitudinal forces generated by the fluid in the expansion cylinder are transmitted by the outer thrust bearing **15** onto the valve plate **7**.

While the construction described above comprises a very advantageous design, further improvements can be achieved by the structure illustrated in which the central pivot **8** is journalled in a bushing **12**, rather than directly in the valve plate **7**, the pivot **8** has less diameter than the diameter of the central bore in the valve plate **7**, and there is a spherical seat **7***b* on the valve plate and a cooperating spherical surface **12***a* on the bushing, whereby a limited angular movement may be accommodated between the pivot **8** and the valve plate **7**. The cylindrical part **12***b* of non-rotating bushing **12** fits somewhat loosely in the valve plate to permit this slight movement, and is sealed by means of the O-rings shown. This compensates for certain inaccuracies in the position of the driving flange relative to the other parts, which is of great advantage, especially with pumps having variable inclination of said driving flange for varying the displacement.

The flow of the high pressure oil from the inlets passes through axial bores or passages **17** in the valve plate **7**, past check valves **18**, thence through radial bores **19** in the valve plate and radial bores **21** in the non-rotating bushing to the longitudinal bore **13** in central pivot **8** via an external annular groove **14** in the pivot **8** and radial bores or ports **22** in pivot **8**. Thus oil flows into the oil-accommodating bore **13**, regardless of any relative rotary positions between pin **8** and bushing **12**. At least some oil escapes along pin **8**, and passes between the thrust bearing or washer **15** and the bushing **12**, so as to sufficiently lubricate the facing thrust bearing surfaces. This leakage is strongly throttled and filtered in the clearance space between the central pivot **8** and the bushing **12**. This is of great importance for the load capacity and life of the thrust bearing **15**.

It is also of advantage to provide lubrication between the expansion or balancing cylinder **10** and the spherical abutment surface or seat **9** on the cylinder block **1**. Said parts may be lubricated by providing ports or bores such as **16** drilled into one or more of the working cylinders. The bores or ports **16** extend between the working cylinder and the enlarged spherical portion of the bore through the cylinder block. By placing the openings of the ports **16** in the working cylinder walls in such away that said openings are covered by the working pistons **2** during part or all of their stroke efficient throttling and filtering of the lubricating oil is provided.

The axial piston pump thus described has the great advantage that the cylinder block is completely kinematically suspended. This means that distance and angular position of the cylinder block relative to the valve plate is only determined by the valve surfaces themselves, which will therefore be, even with inaccurate manufacture or distortions of all other ports, in intimate contact with each other and therefore produce only low leakage losses. The very slightly adjustable guiding of the cylinder block on the central pivot thereby transmits the remaining forces in such a way, that the precise self-adjusting and self-sealing of the cylinder block on the valve surface is not disturbed and that deviations and inaccuracies of the position of the driving flange have only little effect of the position of the connecting rods.

It is therefore clear that the present invention provides a structural arrangement of a hydraulic unit that includes a casing A within which a cylinder block **1** is mounted for rotation. This cylinder block is provided with a plurality of axially extending bores therein, each defining a working cylinder **100**. A working piston **2** is disposed within each bore. As is conventional, the connecting rods of the pistons have a ball-shaped end **3**, so as to make a ball connection with a driving flange **4** mounted for rotation about an axis at an angle to the axis of the cylinder block whereby rotation of the driving flange reciprocates the pistons in the working cylinders, and rotates the cylinder block within the casing. The cylinder block which includes a base having a planar outer surface **101** and ports **6** are provided in the base inwardly of the axes of the working cylinders. Valve plate **7** is fixedly mounted within the casing A, and has a planar surface **70** facing and engaging the planar surface **101** of the cylinder block. The valve plate has inlet passage ways or ports including segmentally-shaped admission and delivery ports **7***a* that open in the planar surface **70** of the valve plate and are adapted to register with the ports **6** in the base of the cylinder block upon relative rotation between the cylinder block and the valve plate. The cylinder block and valve plate each have a centrally disposed axially extending bore therethrough, as shown in **102** and **71**. The axes of these bores are coincident with the axis of the cylinder block. The bore through the valve plate includes an enlarged portion remote from the cylinder block and defined by a portion of the valve plate shaped as a segment of a sphere so as to constitute a seat **7***b*. The bore in the valve plate also has an enlarged portion of an intermediate diameter that is disposed inwardly from the seat **7***b*. The bore through the cylinder block has an enlarged portion disposed inwardly from the face thereof remote from the valve plate and defined by a portion of the cylinder block

shaped as a segment of a sphere and constituting another seat 9. A pivot pin or means 8 is disposed through the bores in the cylinder block and valve plate, with the surface portion of this pin that faces said bores having less external diameter than the diameter of the bores. A ball joint connection 8*a* couples the pivot pin to the driving flange 4. Further, this pivot pin has a portion 8*b* of increased diameter externally of the cylinder block and positioned between this cylinder block and the driving flange. A cup-shaped balancing piston is provided between the cylinder block and the pin 8. This balancing piston 10*b* is in sliding engagement with the enlarged portion 8*b* of the pin. The base of the balancing piston has an external surface 10*a* defined by a segment of a sphere corresponding to and engaging with the seat 9 on the cylinder block. A bushing 12 surrounds the central pin and includes a cylindrical portion 121 that is positioned within the portion of the bore through the valve plate of intermediate diameter, and has less diameter than such portion of the bore so as to fit loosely therewithin. At least a part of the bushing 12 is provided with an external surface 12*a* corresponding to and engaging with the seat 7*b* on the valve plate. A thrust washer 15 is carried by the pin 8 and has a bearing surface facing and in engagement with the bushing 12. Further, the pin 8 has a longitudinal, oil-accommodating bore 13 therein, and radial ports 13*a* extending from said bore and communicating with the space between the pin and the wall portion of the balancing piston 10. The valve plate, bushing and pin are also provided with bores 17 and 19, 21 and 22, respectively, to provide communication between the inlet passages or ports in the valve plate and the bore 13 in the pin 8 via groove 14, so that oil under pressure can flow through the pin to the interior of the balancing cylinder to apply axial thrust against the cylinder block towards the base thereof, into intimate planar contact with the valve plate. The reaction of this axial thrust is absorbed by the thrust washer 15. Furthermore, the cooperating spherical surfaces of the seat 9 on the cylinder block and the surface 10*a* on the base of the balancing cylinder end of the portion or seat or surface 12*a* of the bushing and the seat 7*b* on the valve plate accommodate minute angular deviation between the pin and the cylinder block, and pin and valve plate, respectively, without disturbing such intimate planar contact.

An improved arrangement is illustrated in FIGS. 2 and 3. FIGURE 3 is a view indicating the angular deviation between the axis of the driving flange and the axis of the cylinder block.

In the arrangement of FIG. 2, certain structural features are incorporated differing from those of FIG. 1, in order to provide an improved lubricant distribution system, and one in which a more uniform distribution of hydrostatic pressure is provided on the thrust faces between the bushing and thrust washer relationship. Furthermore, the structural arrangement of FIGURE 2 simplifies manufacture and assembly of the component parts.

In the FIG. 2 arrangement, there is shown a casing A' within which is mounted a cylinder block 1', this cylinder block being rotatable within the casing. A plurality of axially extending bores are provided in the cylinder block so that each define a working cylinder 100'. A working piston denoted generally at 2' is provided within each working cylinder or bore. In this connection, the pistons are cup-shaped, as shown, and the piston rods 3'' are mounted therein so as to provide for slight, angular deviation. The outer end of each piston rod is ball-shaped so as to provide for ball and socket connection with a driving flange 4' mounted for rotation about an axis at an angle to the axis of the cylinder block (see FIG. 3). Obviously, the angularity of the casing and cylinder block relative to the driving flange can be varied, as is known in the art. With this arrangement constituting a drive connection between the pistons and the driving flange, rotation of the driving flange via drive imparted to shaft S reciprocates the pistons in the working cylinders and rotates the cylinder block within the casing.

The cylinder block is provided with a planar outer surface 101', and ports 6' are provided in the base of the cylinder block inwardly of the axes of the working cylinders and in communication with the respective working cylinders. A valve plate 7' is fixedly mounted within the casing A'. This mounting can be of any known structure, including pins or keys or ribs between an external portion of the valve plate and an annulus such as 200 which has external splines so that it can be locked to the casing. The valve plate has a planar surface 70' facing and engaging the planar surface 101' of the cylinder block. The valve plate has segmentally-shaped admission and delivery ports 7*a*' that open in the planar surface 70' of the valve plate, and are adapted to register with the ports 6' in the base of the cylinder block upon relative rotation between the cylinder block and the valve plate. Further, additional ports 700 are provided in the valve plate which are in communication with inlet and outlet passageways IP and OP, respectively, in the casing whereby fluid flow is established through the assembly.

As in the FIG. 1 assembly, both the cylinder block and the valve plate have a centrally disposed, axially extending bore therethrough, shown at 102' and 71', respectively. The axes of these bores are coincident with the axis of the cylinder block. The bore 71' includes an enlarged portion remote from the cylinder block, and defined by a portion of the valve plate shaped as a segment of a sphere so as to constitute a seat 7*b*'. The bore in the valve plate also has an enlarged portion of intermediate diameter disposed inwardly from the seat 7*b*'. The bore through the cylinder block at the end thereof remote from the valve plate has an enlarged portion disposed inwardly from said end or face that is defined by a portion of the cylinder block shaped as a segment of a sphere and constituting another seat 9'. A pivot pin 8' is disposed through the bores in the cylinder block and valve plate, and is of such dimensions that the surface portion of this pin that faces said bores has less external diameter than the diameter of the bores. A ball joint connection 8*a*' couples pivot pin 8' to the driving flange 4'. Additionally, this pivot pin has a portion 8*b*' of increased diameter, externally of the cylinder block, and positioned between the cylinder block and the driving flange. A cup-shaped balancing cylinder 10' is provided between the cylinder block and pin 8'. This cylinder includes a base and wall portion 10*b*' in sliding engagement with the enlarged portion 8*b*' of the pin. The base of the balancing cylinder has an external surface 10*a*' defined by a segment of a sphere corresponding to and engaging with the seat 9' on the cylinder block.

At the other end of the pin there is provided a bushing 12' surrounding the pin and including a cylindrical portion 121' positioned within the portion of the bore 71' of intermediate diameter and of less diameter than said portion, so as to fit loosely therewithin. A portion of the bushing 12' is provided with an external surface 12*a*' of spherical shape corresponding to and engaging with the seat 7*b*' on the valve plate. A thrust washer 15' is carried by the pin 8', and has a bearing surface in facing relation to and engaging with a surface of bushing 12', as described hereinafter.

To provide the improved lubricating and effective thrust distribution arrangement, the pin 8' includes a longitudinal oil accommodating bore 13'. Radial ports 13*a*' extend from the said bore and communicate with the space between pin 8' and the wall portion of the balancing cylinder 10'.

Adjacent the other end of pin 8', radial bores 22' provide communications with the central bore 13' and an annular groove 14' in the pin. The bushing is provided

with radial bores 21' that communicate with said groove at one end and with another annular groove AG on the exterior of the bushing at that part of the bushing that constitutes the spherical surface bearing on seat 7b on the valve plate. The valve plate is provided with bores 18' and 17' that communicate with groove AG at one end and port 700 at the other end, whereby oil under pressure can flow through the various ports and bores to the interior of the balancing cylinder to apply axial thrust against the cylinder block, urging the same toward the valve plate to maintain intimate planar contact between the valve plate and base of the cylinder block.

The other surface of the bushing 12' that faces the thrust washer is provided with a recess R which receives pressure oil flowing along the exterior of the pin and provides for more uniform distribution of the pressure absorbed by the thrust washer, thus allowing higher loads and speeds.

The arrangement just described permits, via the two annular grooves mentioned, effective transmission of oil under pressure between the valve plate, bushing and longitudinal bore in the pin, irrespective of the relative rotary positions of bushing, pin and valve plate.

Furthermore, by utilization of the particular relationship of bores and annular grooves described above, the bushing could be constructed in the form of a slice of a sphere. In other words, the cylindrical portion 121' would be omitted. This would facilitate production and assembly.

While I have shown and described herein only certain embodiments of certain features of my present invention, it is to be understood that they are to be regarded merely as illustrative, and that I do not intend to limit myself thereto, except as may be required by the following claim.

What is claimed is:

1. In an hydraulic unit of the type including a casing, a cylinder block mounted for rotation within the casing, said cylinder block having a plurality of axially extending bores therein each defining a working cylinder, a working piston within each bore, a driving flange mounted for rotation about an axis disposed at an angle to the axis of the cylinder block, a piston rod for each piston, means connecting the piston rods to the driving flange whereby rotation of the flange reciprocates said pistons in the working cylinders and rotates said cylinder block within the casing, said cylinder block including a base having ports therein in communication with the respective working cylinders, said base having a planar outer surface, a valve plate fixedly mounted within the casing and having a planar surface facing and engaging the planar surface of the base of the cylinder block, and said valve plate having inlet passageways therethrough including segmentally shaped admission and delivery ports in the planar surface of the valve plate adapted to register with the ports in the base of the cylinder block upon relative rotation between the cylinder block and valve plate, the improvement comprising said cylinder block and valve plate each having an axial bore therethrough having their respective axes coincident with the axis of said cylinder block, the bore through the cylinder block having an enlarged portion disposed inwardly from the face thereof remote from the valve plate and defined by a portion of the cylinder block shaped as a segment of a sphere and constituting a first seat, the bore through the valve plate including an enlarged portion remote from said cylinder block and defined by a portion of the valve plate shaped as a segment of a sphere and constituting a second seat, a pin including a portion extending through the bores in the cylinder block and valve plate, said portion of the pin having less external diameter than the diameters of said bores, means connecting the end of the pin remote from the valve plate to said driving flange to constitute a ball joint connection between the driving flange and the pin, said pin having a portion of increased diameter externally of said cylinder block and positioned between the cylinder block and the driving flange, a cup-shaped balancing cylinder including a base and a wall portion in sliding engagement with said last-mentioned portion of the pin, the base of said balancing cylinder having an external surface defined by a segment of a sphere corresponding to and engaging with said first seat, a bushing surrounding the central pin and positioned between the and the enlarged portion of the bore through the valve plate, at least a portion of said bushing having an external surface defined by a segment of a sphere corresponding to and engaging with said second seat, said last-mentioned portion of said bushing having at least one transverse bore therethrough, a thrust washer carried by said pin and having a bearing surface in facing engagement with at least another portion of said bushing, said pin having a longitudinal oil-accommodating bore therein and ports extending from said bore and in communication with the space between the pin and the wall portion of the balancing cylinder, said valve plate, the pin also having bores therethrough providing communication between at least one of the ports in the valve plate and the longitudinal oil-accommodating bore in the pin via said at least one transverse bore through the bushing whereby oil under pressure can flow from said at least one port in the valve plate to and through the longitudinal bore in the pin to the interior of the balancing cylinder to apply axial thrust against the cylinder block to urge the base thereof into intimate planar contact with the valve plate, the reaction of said thrust being absorbed by said thrust washer, the cooperating spherical surfaces of said first seat on the cylinder block and the base of said balancing cylinder and of said first-mentioned portion of said bushing and said second seat in said valve plate respectively accommodating minute angular deviations between said pin and said cylinder block and between said pin and said valve plate without disturbing the intimate planar contact between the planar outer surface of the base of the cylinder block and the facing planar surface of the valve plate, said pin having an annular groove in the external surface thereof providing constant communication with the bore through said pin and the longitudinal bore in the pin and said bushing having an annular groove in the spherical surface thereof communicating with the transverse bore through the bushing and providing constant communication with at least one of the bores in the valve plate regardless of the relative rotary positions of pin, bushing and valve plate.

2. In an hydraulic unit of the type including a casing, a cylinder block mounted for rotation within the casing, said cylinder block having a plurality of axially extending bores therein each defining a working cylinder, a working piston within each bore, a driving flange mounted for rotation about an axis disposed at an angle to the axis of the cylinder block, a piston rod for each piston, means connecting the piston rods to the driving flange whereby rotation of the flange reciprocates said pistons in the working cylinders and rotates said cylinder block within the casing, said cylinder block including a base having ports therein in communication with the respective working cylinders, said base having a planer outer surface, a valve plate fixedly mounted within the casing and having a planar surface facing and engaging the planar surface of the base of the cylinder block, and said valve plate having inlet passageways therethrough including segmentally shaped admission and delivery ports in the planar surface of the valve plate adapted to register with the ports in the base of the cylinder block upon relative rotation between the cylinder block and valve plate, the improvement comprising said cylinder block and valve plate each having an axial bore therethrough having their respective axes coincident with the axis of said cylinder block, the bore through the cylinder block having an enlarged portion disposed inwardly from the face thereof remote from the valve plate and defined by a

portion of the cylinder block shaped as a segment of a sphere and constituting a first seat, the bore through the valve plate including an enlarged portion remote from said cylinder block and defined by a portion of the valve plate shaped as a segment of a sphere and constituting a second seat, a pin including a portion extending through the bores in the cylinder block and valve plate, said portion of the pin having less external diameter than the diameters of said bores, means connecting the end of the pin remote from the valve plate to said driving flange to constitute a ball joint connection between the driving flange and the pin, said pin having a portion of increased diameter externally of said cylinder block and positioned between the cylinder block and the driving flange, a cup-shaped balancing cylinder including a base and a wall portion in sliding engagement with said last-mentioned portion of the pin, the base of said balancing cylinder having an external surface defined by a segment of a sphere corresponding to and engaging with said first seat, a bushing surrounding the central pin and positioned between the pin and the enlarged portion of the bore through the valve plate, at least a portion of said bushing having an external surface defined by a segment of a sphere corresponding to and engaging with said second seat, said last-mentioned portion of said bushing having at least one transverse bore therethrough, a thrust washer carried by said pin and having a bearing surface in facing engagement with at least another portion of said bushing, said pin having a longitudinal oil-accommodating bore therein and ports extending from said bore and in communication with the space between the pin and the wall portion of the balancing cylinder, said valve plate, and pin also having bores therethrough providing communication between at least one of the ports in the valve plate and the longitudinal oil-accommodating bore in the pin via said at least one transverse bore through the bushing whereby oil under pressure can flow from said at least one port in the valve

plate to and through the longitudinal bore in the pin to the interior of the balancing cylinder to apply axial thrust against the cylinder block to urge the base thereof into intimate planar contact with the valve plate, the reaction of said thrust being absorbed by said thrust washer, the co-operating spherical surfaces of said first seat on the cylinder block and the base of said balancing cylinder and of said first-mentioned portion of said bushing and said second seat in said valve plate respectively accommodating minute angular deviations between said pin and said cylinder block and between said pin and said valve plate without disturbing the intimate planar contact between the planar outer surface of the base of the cylinder block and the facing planar surface of the valve plate, said pin having an annular groove in the external surface thereof providing constant communication with the bore through said pin and the longitudinal bore in the pin, said bushing having an annular groove in the spherical surface thereof communicating with the transverse bore through the bushing and providing constant communication with at least one of the bores in the valve plate regardless of the relative rotary positions of pin, bushing and valve plate and said bushing including a face directed toward said thrust washer, said face having a recess therein defining a rim engaging said thrust washer and an oil-accommodating chamber between said bushing and thrust washer to provide effective pressure distribution.

3. The arrangement as claimed in claim 1 and said bushing being shaped as a slice of a sphere.

References Cited by the Examiner

UNITED STATES PATENTS

2,463,299	3/49	Nixon	103—162
3,079,870	3/63	Thoma	103—162

LAURENCE V. EFNER, *Primary Examiner.*