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 [21] Appl. No. **38,181**
 [22] Filed **May 18, 1970**
 [45] Patented **Oct. 12, 1971**
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[54] **AXIAL PISTON DEVICE**
14 Claims, 9 Drawing Figs.

[52] U.S. Cl. **91/490,**
91/507, 91/501

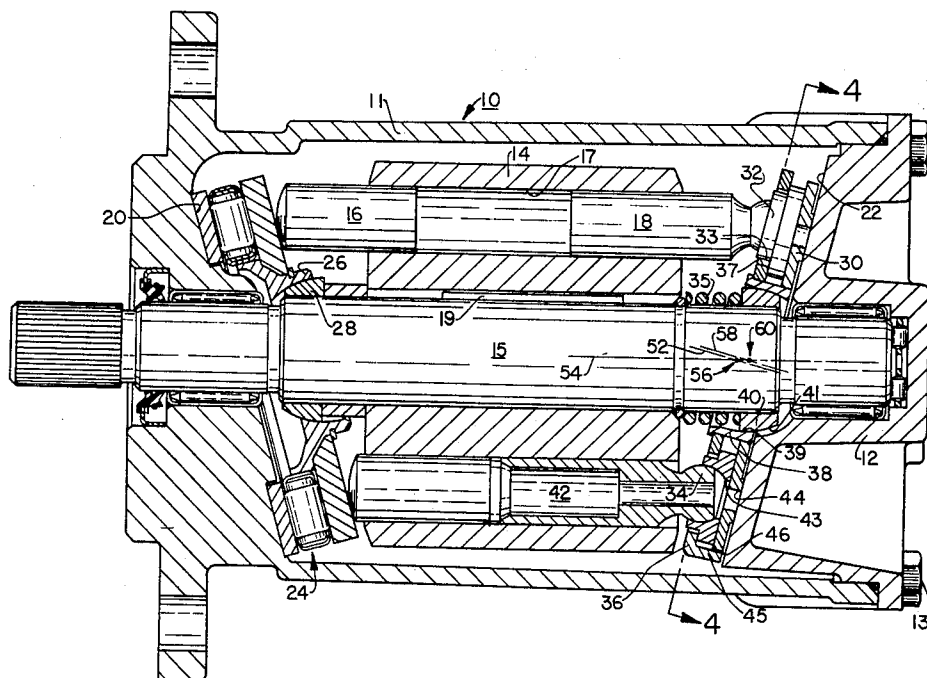
[51] Int. Cl. **F04b 1/10,**
F04b 1/20

[50] Field of Search **91/485,**
499, 501, 507, 490

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ABSTRACT: An axial piston barrel device having slipper shoe contacting an inclined or inclinable cam wherein a shoe-engaging cage or spider plate is positioned nonconcentrically to the slipper shoes, so that a shoe drivingly engages the spider plate only when moving while on the retraction portion of the cycle. One form of the invention offsets the center axis of the spider plate from the shoe axis toward the outermost piston position so that each shoe engages the spider only on inward stroke even if rotation or cam angle is reversed.



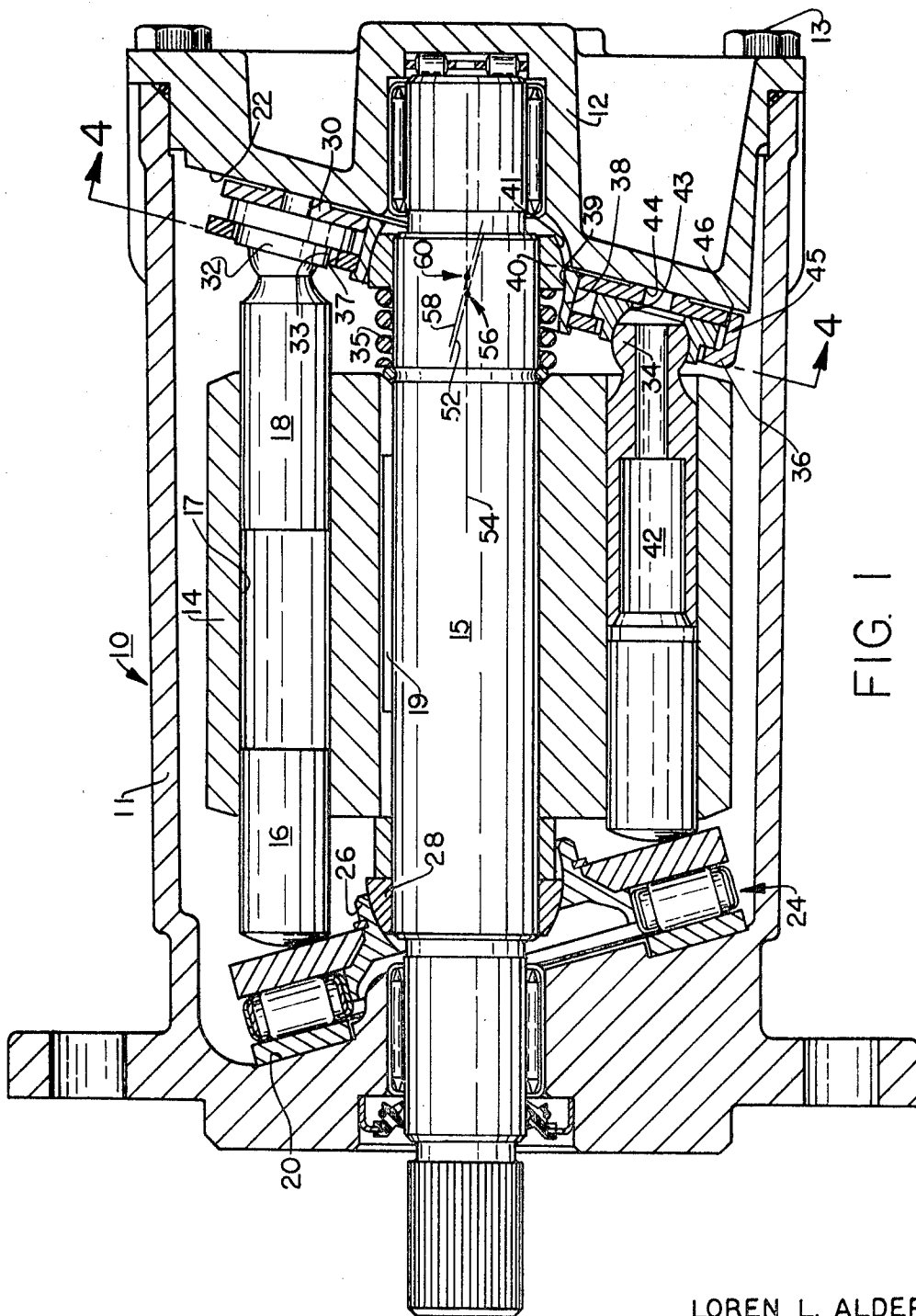
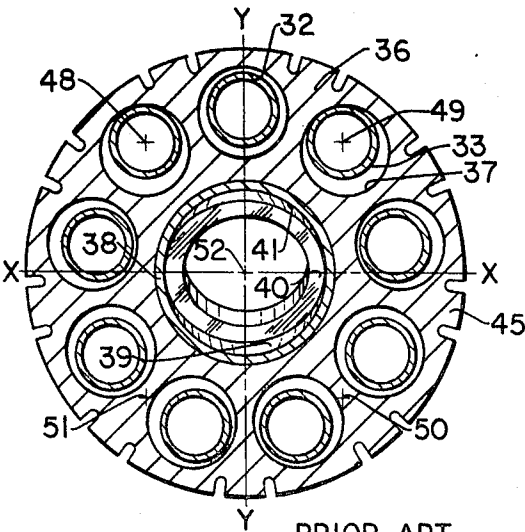


FIG. 1

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PRIOR ART
FIG 2

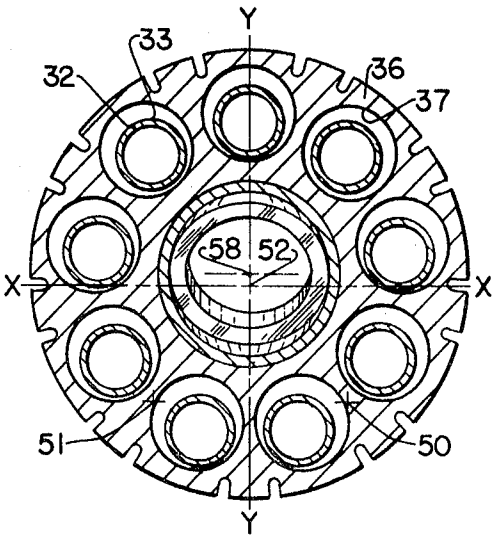
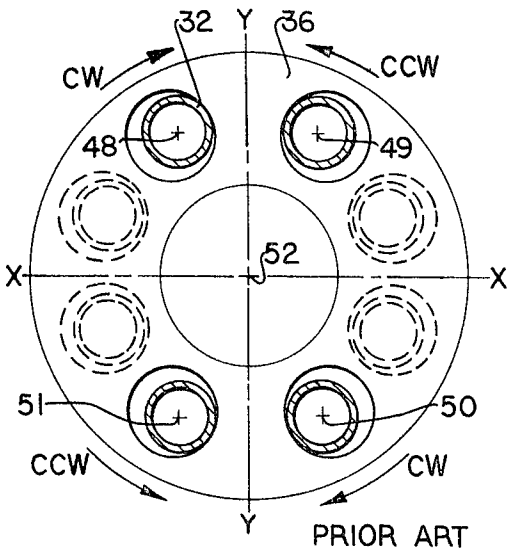


FIG 4



PRIOR ART
FIG 3

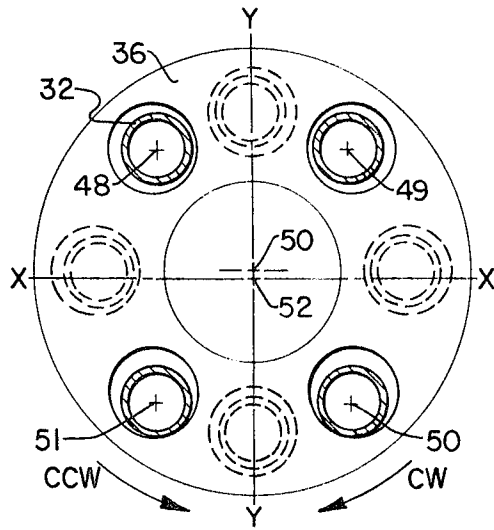


FIG 5

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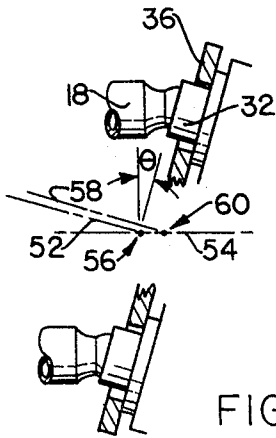


FIG 6

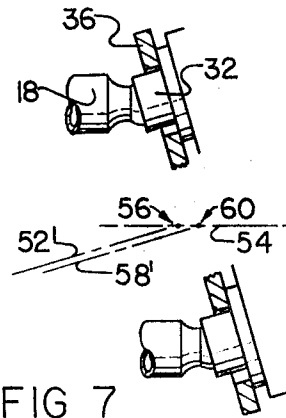


FIG 7

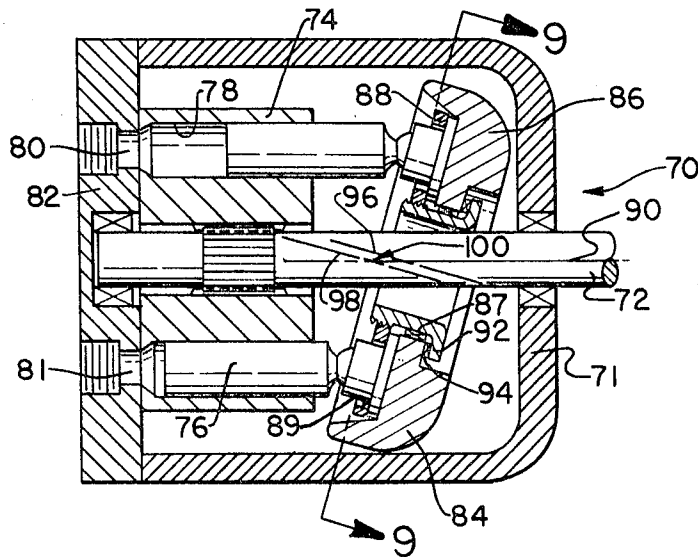


FIG 8

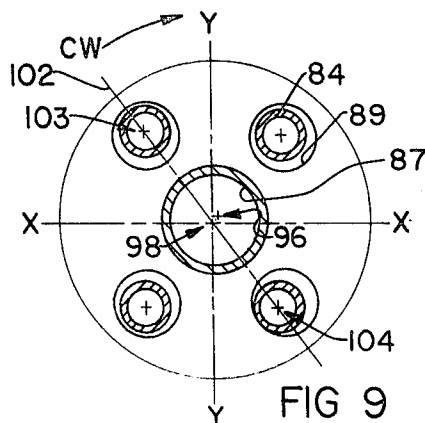


FIG 9

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AXIAL PISTON DEVICE

CROSS REFERENCE TO RELATED APPLICATION

Reference is made to related copending Application Ser. No. 37,946 of Frank N. Alexander and Loren L. Alderson, filed concurrently herewith and commonly assigned.

BACKGROUND OF INVENTION

This invention relates to axial piston devices of the type utilizing pistons with slippered shoes. More particularly, this invention provides an improved means for transferring driving torque to the spider plate from the piston-shoe assemblies.

The class of axial piston devices to which the invention pertains generally includes a rotary cylinder barrel or block having a plurality of circumferentially spaced cylinders in which pistons are reciprocal. The pistons extend outwardly from the barrel to cooperate with an inclined or inclinable cam surface which induces piston axial reciprocation upon block rotation. Slipper shoes, pivotally attached to the outer piston ends, extend through a unitary spider plate to cooperate with the cam surface. Such spider plates transfer biasing forces to the pistons to maintain contact between the cam and shoes as well known to the art, and also transfer driving torque to shoe-engaging bearing plates as set forth in the aforementioned copending patent application.

The reaction to driving torque transmitted from the piston and shoe to the spider plate exerts side loading on the pistons and is a major cause of piston friction between the pistons and cylinders of the barrel. When a piston is moving outwardly from the cylinder barrel, this side load induces binding and sticking of the piston and disengagement of the slipper shoes from the cam surface. The result is loss of the fluid bearing between the shoes and cam surface and ensuing seizure and destruction of the unit. On the other hand, a piston experiencing such friction while on its inward stroke does not cause destructive shoe disengagement or lift-off, as the shoe is moving inwardly through its contact or cooperation with the cam surface.

It would be highly advantageous, therefore, to provide an axial piston device wherein a piston does not transmit driving torque to the spider when on its outward stroke.

SUMMARY OF INVENTION

Accordingly, it is a primary object of the present invention to provide an improved axial piston device wherein a piston transmits spider driving torque only during that portion of the barrel rotation cycle when it is retracting into the cylinder barrel.

A more specific object is to provide a spider plate for an axial piston device eccentrically located relative to the piston shoes to eliminate driving contact therebetween during the piston outward stroke.

Another object of this invention is to furnish an axial piston pump or motor construction having piloting means eccentrically located relative to the shoes to radially position and locate the spider plate eccentric with respect to the shoes.

For an axial piston device made in accordance with any of the preceding objects, it is an object of this invention to provide a pump or motor construction that eliminates piston and spider contact during piston outward stroke for both bidirectional rotation and flow.

Another object of the invention is to space the spider plate rotational axis from the slipper shoe rotational axis in a direction toward the fully extended piston position so that shoe-spider contact occurs only within 90° of the fully retracted piston position.

A further object of the invention is to locate the slipper shoes and spider plate such that the shoe rotational axis intercepts the drive shaft axis at a point nearer the cylinder block than does the spider rotational axis.

Briefly, one embodiment contemplates a centrally located pivot arrangement that radially pilots the spider plate to the drive shaft. The pivot center intersects the drive shaft axis at a

position displaced a predetermined distance from the intersection of the plane containing the piston sphere end centers with the drive shaft rotational axis, in a direction away from the cylinder barrel. This locates the spider plate relative to the shoes so that a piston and shoe drivingly engage the spider plate only once per revolution at a position where the piston is in its retracting stroke.

Other objectives and advantages of the present invention are set forth or will become apparent from the following detailed description and accompanying drawings, in which:

FIG. 1 is a longitudinal section view of an axial piston device embodying the present invention;

FIG. 2 is a view, similar to FIG. 4, of a prior art device;

FIG. 3 is a sectional view, similar to FIG. 5, illustrating a prior art device;

FIG. 4 is a partial view taken along line 4—4 of FIG. 1;

FIG. 5 is a schematic representation of various angular positions of a piston shoe 32 and associated hole of the spider plate, with the critical positions shown by solid lines;

FIG. 6 is a section view of the shoes and spider plate of FIG. 1;

FIG. 7 is a section view like FIG. 6 showing an oppositely inclined cam;

FIG. 8 is a longitudinal section view of another form of axial piston device that incorporates another embodiment of the invention; and

FIG. 9 is a schematic similar to FIG. 5 oriented along line 9—9 of FIG. 8.

FIG. 1 EMBODIMENT

FIG. 1 illustrates an axial piston pump or motor, generally designated by the numeral 10, of the double-ended type utilizing pairs of opposing pistons 16 and 18 reciprocal in each through cylinder bore 17 of a cylinder barrel or block 14. The unit has an outer housing comprised of a hollow casing 11 secured by bolts 13 to an end plate 12 closing one end of the casing. Key 19 drivingly interconnects the axially extending shaft 15 and cylinder block 14, the shaft driving the cylinder barrel for pumping operation and the barrel driving the shaft for motoring function.

Pistons 16 and 18 extend from barrel 14 to cooperate with oppositely inclined surfaces 20 and 22 of casing 11 and end plate 12 which induce piston axial reciprocation as the barrel rotates. A central pivot 28 and member 26 radially pilot and locate a mechanical bearing assembly 24 interposed between pistons 16 and surface 20 to absorb axial thrust of pistons 16. Similarly, at the opposite end of the unit, a connector plate 30, located intermediate inclined cam surface 22 and slipper shoes 32 absorbs axial thrust of pistons 18. Shoes 32 have inner spherical sockets pivotally swaged upon the outer cooperating piston surfaces 34, and the shoes 32 extend through enlarged holes 37 of spider or cage plate 36 which engages the enlarged flanges of the slipper shoes. Radially locating both spider 36 and connector plate 30 are central pilot 38 and pivot 40 which have cooperating spherical surfaces 39 and 41 permitting relative oscillation therebetween during unit operation. Spring 35 exerts a light biasing force urging the shoes and pistons 18 toward connector plate 30 by acting against the shoe flanges through pivot 40 pilot 38 and spider plate 36.

Piston bores 17 communicate with inclined surface 22 through aligned interior passages 42, 43 and 44 in the pistons, shoes and connector plate respectively, a separate connector plate passage 44 provided for each shoe interior passage 43. Opening onto cam surface 22 and thereby communicating with piston bores 17 are separate fluid inlet and discharge valving passages (not shown) in end plate 12 that communicate with external inlet and outlet ports in the end plate. The valving passages, conventional and well known to the art, consist of separated arcuate slots on surface 22 aligned with connector plate passages 44. During the half-revolution when the pistons are moving axially outwardly, bores 17 communicate

with one of the arcuate slots, and during the other half-revolution when the pistons are retracting back into bores 17, the bores 17 then communicate with the other valving slot. A hydrostatic fluid bearing maintained at the connector plate and cam interface absorbs axial thrust from pistons 18 created by pressure in the piston bores. Pressure fluid from bores 17 leaks between the cooperating flat surface of connector plate 36 and end plate surface 22 to establish the fluid bearing.

Pistons 18 transmit rotary driving torque to spider 36 at the point of contact of the outer surface 33 of a slipper shoe with the wall of the associated spider hole 37. The spider and connector plate drivingly engage through a tooth 45 and groove 46 connection at their periphery, and the connector plate 30 rotates in synchronization with the spider plate 36, pistons and cylinder block.

Unit 10 is disclosed in the aforementioned copending U. S. Application Ser. No. 37,946, to which reference may be made for a further description of the structure and operation of the device, although not necessary to the understanding and practice of the present invention.

The present invention relates to a novel manner of transmitting driving torque from the shoes to the spider wherein a shoe 32, as shown in FIG. 5, contacts spider 36 only once per revolution such as at position 50 where the pistons are on retraction stroke. In contrast, the shoe of the conventional prior art device engages the spider twice each revolution such as at positions 48, 50 as shown in FIG. 3, on both retraction and outward strokes of the pistons.

Illustrating conventional prior art structure, the FIG. 2 view taken perpendicular to the inclined cam surface shows the relative positions of shoes 32 to spider plate holes 37 and also the central pivot 40 that appears of ellipsoidal form in this view. The axis 52 about which spider plate 36 rotates is, of course, perpendicular to the inclined spider plate and appears as a point. The axis of rotation of shoes 32 is parallel to spider plate axis 52 since each shoe, as shown in FIG. 1, is inclined with the spider plate; and, as characteristic of prior devices, the axis of rotation of the shoes is not only parallel but also coincident and common to the spider axis 52. The prior art common axis 52 intersects the shaft axis 54 at point 56 in FIG. 1, which is the intersection of the plane containing the centers 56 of piston spherical ends 34 with shaft axis 54, because shoes 32 are constrained to sphere ends 34. Accordingly, prior art devices conventionally locate the centers of the pilot and pivot spherical surfaces 39 and 40 at point 56 to specify common shoe and spider axes. For instance, typical of the prior art is U.S. Pat. No. 2,776,627 to Keel which requires that the pivot spherical center and the pilot conical bore axis intersect the drive shaft axis at the same point that the plane containing the centers of the piston ends intersects the shaft axis.

The purpose of common shoe and spider axes, as well known in the art, is to minimize relative movement between the shoe and spider which arises from shoes 32 moving in an elliptical path about axis 52, rather than tracing a circular path as does spider 36. Attaching and constraining the shoes to rotate with the pistons 18 about shaft axis 54 causes their elliptical movement about shoe axis 52 inclined to the shaft axis. The common axis 52 keeps the shoe elliptical path and spider circular path as nearly coincident as possible to minimize relative movement. It is to be understood that describing the shoe path as elliptical and the spider path as circular is the result of analysis of shoe and spider movement relative to axes oriented perpendicularly to the inclined cam surface. Similar analysis made relative to axes oriented perpendicularly to the axial pistons would show the shoes to follow a circular path and the spider to take an elliptical pattern. The operation and function, of course, is identical regardless of the manner of analysis, the important consideration being that, relative to one another, the shoes and spider trace circular and elliptical patterns.

In consequence of coincident shoe and spider axes, however, a shoe 32 can contact the wall of spider hole 37 in each quadrant during one revolution at four points 48-51, as shown

in FIG. 3 which is a schematic illustration of the positions taken by a shoe relative to its associated hole 37 at various angular positions of the shoe around axis 52. The points 48-51 represent the center of a shoe 32 when its surface 33 is engaging the wall of spider hole 37. Solid lines illustrate the four possible positions of contact and the dashed lines depict other exemplary intermediate positions. A slipper shoe engages the spider plate in two of these positions: for clockwise rotation of the shoe and spider, the driving points are 48 and 50; while for counterclockwise rotation, they are points 49 and 51. Considering the shoes and spider as rotating clockwise about axis 52 with the cam positioned as in FIG. 1, the pistons and shoes are on the outward portion of their stroke when left of line Y-Y in FIGS. 2 and 3, and move inwardly during their retraction stroke when positioned right of line Y-Y. Thus, every piston experiences sizable side load on its outward stroke upon reaching position 48, and again on its inward stroke when reaching point 50. The piston side load causes slight cocking, binding and sticking of the piston in bore 17. Upon occurring at point 48 on the outward stroke, the force pushing the piston against connector plate 30 may be insufficient to overcome the high frictional drag induced by the side load, and the driving shoe 32 will lift off and lose contact with the connector plate. Seizure and destruction of the shoes and entire unit can ensue immediately due to the loss of the fluid pressure bearing between shoe and connector plate 30. Side load experienced at point 50 on the inward stroke does not induce shoe lift-off, however, since the shoe and piston are then moving inwardly through cooperation with the connector plate and inclined cam surface.

When rotating counterclockwise, the retraction and withdrawal portion of the piston stroke reverse sides relative to line Y-Y; the piston and shoe experience side load on outward stroke at point 49 which induces destructive shoe lift-off, and the piston and shoe experience nondestructive side load at position 51 during the inward stroke.

The present invention concerns the elimination of driving contact and destructive shoe lift-off during the outward piston stroke. To this end, as shown in FIGS. 1 and 4-6, the spider plate rotational axis 58 is not coincident to the slipper shoe axis 52. Shifting the spider plate 36 and its axis 58 upwardly on line Y-Y relative to the shoes 32 and their axis 52, toward the position taken by a piston when withdrawn the maximum distance from bore 17, prevents engagement of the shoes with the spider above line X-X and at points 48 and 49 of FIG. 5. Rather, engagement may occur only below line X-X at the lower points 50, 51 within ninety degrees of the innermost position of a piston in bore 17. Thus, a shoe 32 rotating clockwise engages the spider plate only at one point 50 which occurs during the piston inward stroke. Similarly, when rotating counterclockwise, the shoe engages only at point 51, again during the piston inward stroke.

It will be understood that a shoe 32 engages the spider in an angular band about the point 50 or 51 and remains in engagement until a succeeding shoe enters the band to contact and drive the spider. The spider is in substantially continuous driven engagement with the shoes though only about the position 50 or 51. The number of pistons utilized in the unit primarily determines the angular width of such band. For nine piston units as shown, the band extends approximately 20° either side of point 50, 51. Throughout the specification, reference to a shoe engaging the spider at a particular angular position implies an engagement over such an angular band, and that the spider is in substantially continuous driven engagement with one shoe or another.

In FIG. 1, the centers of pivot and pilot spherical surfaces 39 and 41 lie at position 60 on shaft axis 54 remote from point 56 in an axial direction away from cylinder block 14. As seen in FIGS. 4 and 5, this displaces the rotating axis 58 of the spider plate upwardly from shoe axis 52 so that shoes 32 lose contact with the spider at shoe positions 48 and 49. This accordingly requires a slightly larger size hole 37 in the spider as compared to the FIG. 2 prior art, due to the greater relative

movement between shoe and spider induced by their noncoincident axes. Spider 36 and its axis 58 move upwardly relative to the shoes by a distance equal to the distance between points 56 and 60 multiplied by the sine of the angle of inclination of the cam surface.

Axis 58 need only be located upwardly from shoe axis 52 and infinitesimal amount, theoretically, to eliminate undesirable contact at points 48 and 49; however, practical manufacture requires the axis 58 be moved a sufficient distance to compensate for tolerances of the various mating parts to assure that the shoes will not contact the spider during their outward stroke. It will be apparent to those skilled in the art the art tolerances to consider in determining proper spacing between the shoe and spider axes. In FIG. 1, for instance, part tolerances taken into account include: distance between bores 17 in cylinder barrel 14; concentricity of the piston sphere end 34 to the major diameter of piston 34 in bore 17; diameter of the shoe driving surface 33; concentricity of this same surface 33 to the shoe spherical socket cooperating with piston end 34; diameter of spider holes 37; the distance between spider holes 37; concentricity of the inner and outer pilot 38 surfaces; and concentricity of the inner and outer surfaces of pivot 40. Of these, the more critical relative to shoe and spider engagement are the location of bores 17 within the cylinder block and the location of spider plate holes 37. The following empirical formula approximates the minimum space between points 56 and 60 required in practical manufacture:

$$x = \frac{2(b+h)}{\sin \theta}$$

where:

x = minimum space between points 56 and 60;

b = tolerance of location of a bore 17 from its nominal position;

h = tolerance of location of a hole 37 from its nominal position;

θ = angle of inclination of surface 22 to a plane perpendicular to drive shaft axis 54 as shown in FIG. 6

In design of a unit as in FIG. 1 whose general overall size is specified by about a one inch radius for the circle containing the centers of bores 17, the tolerance of the location of bores 17 is $\pm 0.005''$, and the tolerance of hole 37 location is $\pm 0.0025''$. Thus, the above equation becomes:

$$x = \frac{.015''}{\sin \theta}$$

This specifies a spacing of about $0.015''$ between the shoe and spider axes 52 and 58 to eliminate undesired contact at points 48 and 49. Thus, for a cam angle of 14° , the axial spacing between points 56 and 60 becomes about $0.060''$. In the case of a variable displacement less than maximum. It will be apparent that both these formulas are primarily dependent upon various part tolerances and will alter in form dependent upon modification of the parts and their acceptable tolerances.

The present invention is particularly advantageous in a unit as in FIG. 1 where fluid is ported through the pistons and shoes to bores 17. The pistons and shoes must transmit a greater rotary torque to the spider plate to additionally drive the connector plate 30, and the greater torque increases the piston side load and chances for shoe lift-off. Further, disengagement of a shoe 32 from the face of connector plate 30 creates another problem: an open path for the entire flow to escape from passages 42 and 44 to the housing interior. Sudden dumping of such a large fluid volume into the interior can rupture casing 11. By eliminating a cause of shoe lift-off, this invention prevents such housing destruction.

The invention is equally useful in variable displacement units wherein the inclination of surface 22 can be selectively varied, including "overcenter"-type units wherein surface 22 can tilt either direction from a plane perpendicular to the pistons to create reversible flow from the unit. In the FIGS. 6 and 7 illustrating such opposite cam inclinations, the spacing of pivot center 60 forwardly from point 56 moves the spider

plate upwardly toward the fully extended piston position in FIG. 6 as described before, so that shoe-spider contact occurs within 90° of the fully retracted piston position; yet it also results in downward movement of spider plate 36 and axis 58' in FIG. 7, again toward the fully extended piston position. The driving contact points in FIG. 7 are again within 90° of the fully retracted piston positions, but at upper points 48 and 49 rather than the driving points 50 and 51 in the FIG. 4-6 embodiment. The contact at position 48 or 49 (depending upon direction of piston rotation) is during piston inward stroke, and there is no engagement at point 50 or 51 where the piston is moving outwardly.

Spacing of pivot center 60 rightwardly away from the cylinder block relative to point 56 thus assures that spider driving contact occurs only on piston inward stroke, regardless of direction of piston rotation and regardless of the direction of cam inclination. As the cam angle approaches zero where surface 22 is perpendicular to the shaft axis, the shoe and spider axes are coincident as prior art devices lying upon shaft axis 54. Shoe lift-off is also of less concern at small cam angles as the piston 18 is not extending as far from the bore and will not bind or stick as easily.

FIG. 8 EMBODIMENT

FIG. 8 illustrates an alternate manner of incorporating the invention into an axial piston unit, and also shows a different piston pump construction wherein the spider plate is piloted to the inclined cam plate rather than to the drive shaft through a pivot as in FIG. 1.

The axial piston pump or motor 70 of FIG. 8 has an axially aligned drive shaft 72 extending through the housing 71 to drivingly engage the rotary cylinder barrel 74. Pistons 76 reciprocate in bores 78 to displace fluid in and out these bores through valving slots 80 and 81 of backplate 82. The backplate sealingly mates with a transverse face of the cylinder block and has inlet and outlet fluid ports communicating with the valve slots 80, 81. Slipper shoes 84, swaged to the piston outer spherical ends as in FIG. 1, directly contact and slide upon the face of inclined and nonrotating cam plate 86. The shoes extend through enlarged holes 89 of the cage or spider plate 88 which engages the larger diameter lips of shoes 84 to maintain same in fairly close proximity to the cam surface. The pistons and cylinder barrel 74 synchronously rotate clockwise, as viewed in FIG. 9, with shaft 72 about axis 90 during unit operation, and fluid pressure bearings fed with fluid from bores 78 lubricate the relatively rotating interfaces of cylinder block 74 against backplate 82 and shoes 84 against cam plate 86.

Bore 87 of cam plate 86 radially guides and pilots spider plate 88. A central piloting member 92 threadably secured to the spider plate rides upon bearings 94 interposed between the rotating pilot 92 and nonrotating cam plate. Thus, the central axis 96 of piloting bore 87 is also the rotational axis of spider plate 88.

In accordance with the present invention, the central axis of piloting bore 87 is eccentric to the drive shaft axis to offset the spider plate rotational axis 96 from the rotational axis 98 of shoes 84. Axis 98 intersects drive shaft axis 90 at point 100 which, again, is the point on the shaft axis intersected by a plane containing the centers of the pistons outer spherical ends. FIG. 9 clearly illustrates axis 96 as located upwardly and rightwardly of shoe axis 98 in a direction perpendicular to a line 102 intersecting the center positions 103 and 104 of a shoe 92. Positions 103 and 104 correspond to the two driving positions 48 and 50 of the FIG. 3 prior art when the shoes rotate clockwise. By straightforward geometric considerations, it will be apparent that locating the spider axis from the shoe axis in this direction entails the minimum spacing between axes 96 and 98 and minimum size of spider holes 89, while gaining maximum separation between the shoe and spider hole wall at position 103 to incorporate the advantages of the present invention.

Such location of spider axis 96 prevents driving engagement between the shoe 84 and spider plate at point 103 and on the left side of axis Y—Y where the piston and shoes are on their outward stroke. The single-driving point is at 104 on the piston inward stroke. Accordingly, this arrangement precludes piston cocking and shoe lift-off in the same manner as described in the FIG. 1 embodiment.

Locating the spider axis 96 as in FIG. 9 does not, however, incorporate with it the operability of the present invention for both directions of piston rotation and for opposite inclinations of the cam surface as does the FIG. 1 arrangement. Spider axis 96 may, of course, be located in the same position as axis 58 of FIG. 1 relative to the shoe axis, by positioning axis 96 vertically upwardly from axis 98 on line Y—Y in FIG. 9. This is particularly effected with ease in a variable displacement unit utilizing a spider plate piloted to a cam plate rockable about a transverse axis, by locating this cam plate transverse axis to intersect the drive shaft axis at a position corresponding to the point 60 of FIG. 1. This accordingly positions the spider plate axis like axis 58 of FIG. 1 to embody the operation and advantages of the invention described for the FIG. 1 arrangement.

Other arrangements and additional modifications and variations of locating the spider plate axis to produce the desired driving points between shoe and spider will be apparent. Accordingly, the specific embodiments illustrated and described, as well as the specific references to dimensions of the various parts, are to be considered exemplary in nature and not limiting to the scope and spirit of the invention so far as set forth in the appended claims.

Having described my invention with sufficient clarity that those skilled in the art may practice and use it, I claim:

1. An axial piston device comprising a housing having fluid inlet and outlet ports; a drive shaft extending axially within the housing; a cylinder block drivingly affixed to the shaft and having a plurality of concentric axial bores alternately communicating with the inlet and outlet ports upon cylinder block rotation; a piston reciprocally disposed in each bore and having an outer spherical end; a slipper shoe pivotally attached to each piston outer spherical end, the shoes rotary about a common central axis; an inclined or inclinable cam surface mounted in the housing cooperating with the shoes to permit inward and outward piston reciprocation between fully retracted and fully extended positions upon cylinder block rotation; a cage plate aligned parallel to the inclined cam surface and positioned to engage said shoes, said plate having openings through which the shoes extend and drivingly contact the plate; and pilot means engaging said cage plate and radially constraining same to rotate about a rotational axis parallel to and spaced from said shoe central rotational axis whereby each shoe drivingly contacts the cage plate only during inward reciprocation of the attached piston.

2. The device of claim 1 wherein said cage plate rotational axis is spaced apart from said shoe rotational axis toward said fully extended piston position whereby each shoe drivingly contacts the cage plate upon cylinder block rotation only when angularly positioned within 90° of the fully retracted piston position.

3. The device of claim 1 wherein said shoe and cage plate each rotate about respective axes perpendicular to the inclined surface which axes intercept the rotational axis of the drive shaft at first and second positions respectively, said first position being located nearer the cylinder block than said second position.

4. The device of claim 3 wherein said first position is located at a point where a plane containing the centers of the spherical ends of said pistons intercepts the shaft rotational axis.

5. In an axial piston device having a cylinder block drivingly affixed for rotation with an axially extending shaft, pistons disposed in concentric axial bores of the cylinder block for inward and outward movement therein so that fluid is alternately received and expelled from the bores through valving passages communicating therewith, the pistons having spheri-

cally shaped outer ends extending from said bores to cooperate with a cam member inclined or inclinable to the pistons to induce piston reciprocation, an associated slipper shoe universally attached to each piston spherical outer end, said shoes cooperating with said cam member and rotative about a central axis inclined to the shaft axis, and a spider plate oriented parallel to said member and in driven engagement with the shoes, wherein the improvement comprises:

pilot means engaging and radially locating said spider plate to rotate about an axis parallel to said shoe central axis, said spider plate axis displaced from said shoe central axis a predetermined distance whereby a slipper shoe central axis a predetermined drivingly engages the spider plate only during inward movement of its associated piston.

6. The device of claim 5 wherein said pilot means comprise a centrally located pilot member engaging the spider plate and a pivot constrained to the shaft, the pilot member and pivot having cooperating concentric spherical surfaces where common center lies on said shaft axis at a position displaced from the intersection of said shoe central axis with the shaft axis in a direction away from the cylinder barrel.

7. The device of claim 5 wherein said pilot means comprise the inclined cam member and a pilot member guided upon the cam member and secured to radially position the spider plate.

8. The device of claim 7 wherein said pilot member is of a cylindrical shape closely cooperating with a bore in the inclined cam member, the axis of said cam bore being parallel and eccentric to said rotational axis.

9. The device of claim 5 wherein said pilot means locates the spider plate so that said spider plate axis is displaced from said shoe central axis in a direction toward the outermost position of a piston in its cylinder bore whereby a shoe contacts the spider plate only when angularly positioned within in ninety degrees of the innermost position of a piston in its cylinder bore and only during inward movement of its associated piston.

10. In an axial piston device having a cylinder block drivingly affixed for rotation with an axially extending shaft, pistons reciprocally disposed in concentric axial bores in the cylinder block and having spherically shaped outer ends adjacent a cam surface inclined or inclinable at an acute angle relative to a plane perpendicular to the axis of said shaft, said shaft axis being intersected at a first point by a plane containing the centers of said spherical surfaces in said piston ends, slipper shoes pivotally attached to said piston spherical ends, a flat connector plate interposed between and sealingly contacting said shoes and the inclined cam surface, conduit means extending through each piston and shoe and the connector plate to said cam surface to alternately connect said axial bores upon cylinder barrel rotation with inlet and outlet passages opening onto said cam surface, a spider plate engaging said shoes to maintain the shoes in close proximity to the connector plate, said spider having enlarged holes through which the shoes extend and drivingly engage the spider plate, and pilot means supported on the shaft universally joined to the spider and connector plates to radially locate same to the shaft, wherein the improvement comprises:

said shoes rotative about a central axis extending perpendicularly to the inclined cam surface and intercepting the shaft axis said first point; and

the spider and connector plates arranged parallel to the inclined cam surface with a common rotational axis parallel to said shoe rotational axis intercepting the shaft axis at a second point spaced from said first point in a direction away from the cylinder block.

11. The device of claim 10 further comprising an oppositely extending second piston in each axial bore and a second inclined cam surface cooperating with said second pistons to reciprocate same in the axial bores.

12. The device of claim 10 wherein said pilot means include a pilot member contacting the spider and connector plates and a pivot constrained to the shaft, said pilot member and pivot universally joined upon cooperating concentric spherical sur-

9

faces whose common center lies on the shaft axis at said second point.

13. The device of claim 10 wherein the minimum distance between said first and second points on the shaft axis is determined approximately as

$$x = \frac{2(b+h)}{\sin \theta}$$

where:

- x = minimum distance between said first and second points
- b = maximum allowed variation of the location of one of said axial bore from its nominal location;
- h = maximum allowed variation of the location of one of

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said spider holes from its nominal location; and
θ = said acute cam angle.

14. The device of claim 10 wherein the minimum distance between said first and second points on the shaft axis is determined approximately as

$$x = \frac{.015 \text{ inches}}{\sin \theta}$$

where:

- x = minimum distance between said first and second positions; and
- θ = said acute cam angle.

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