United States Patent

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[54] SWASH PLATE DEVICE

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[52] **U.S. Cl.** **91/487,** 91/487

[51] **Int. Cl.** **F04b 1/02**

[58] **Field of Search** 91/485–489

[56] **References Cited**

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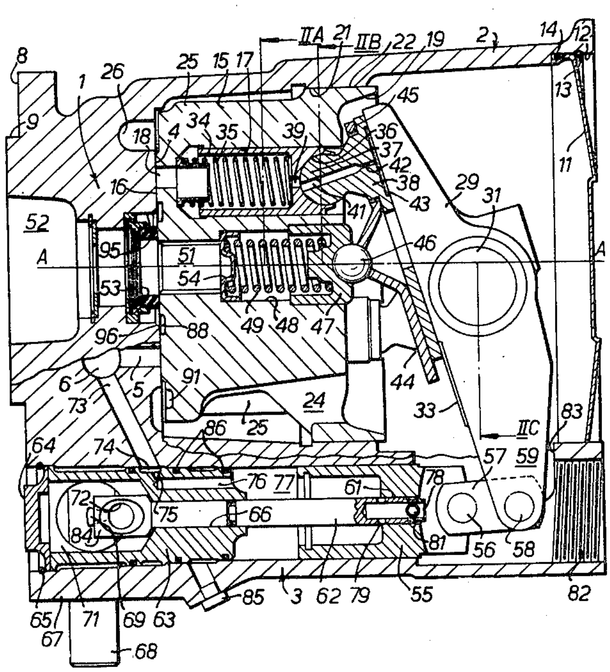
[57] **ABSTRACT**

A swashplate pump or motor in which the drive shaft is arranged to extend from the cylinder block through an aperture in the valve on which the cylinder block rotates, the aperture being open outwardly to the atmosphere. A circular seal is provided in the valve means to engage a flat surface at the end of the cylinder block whereby to form a seal against escape of liquid from the valve into the aperture. A circular groove is formed in the valve or the cylinder block in between the seal and the ports in the valve means and is connected to the low-pressure port whereby liquid at low pressure in the low-pressure port provides a low-pressure zone within the groove to prevent centrifuging of air from the aperture over the surface of the seal and into the swashplate pump or motor.

6 Claims, 5 Drawing Figures



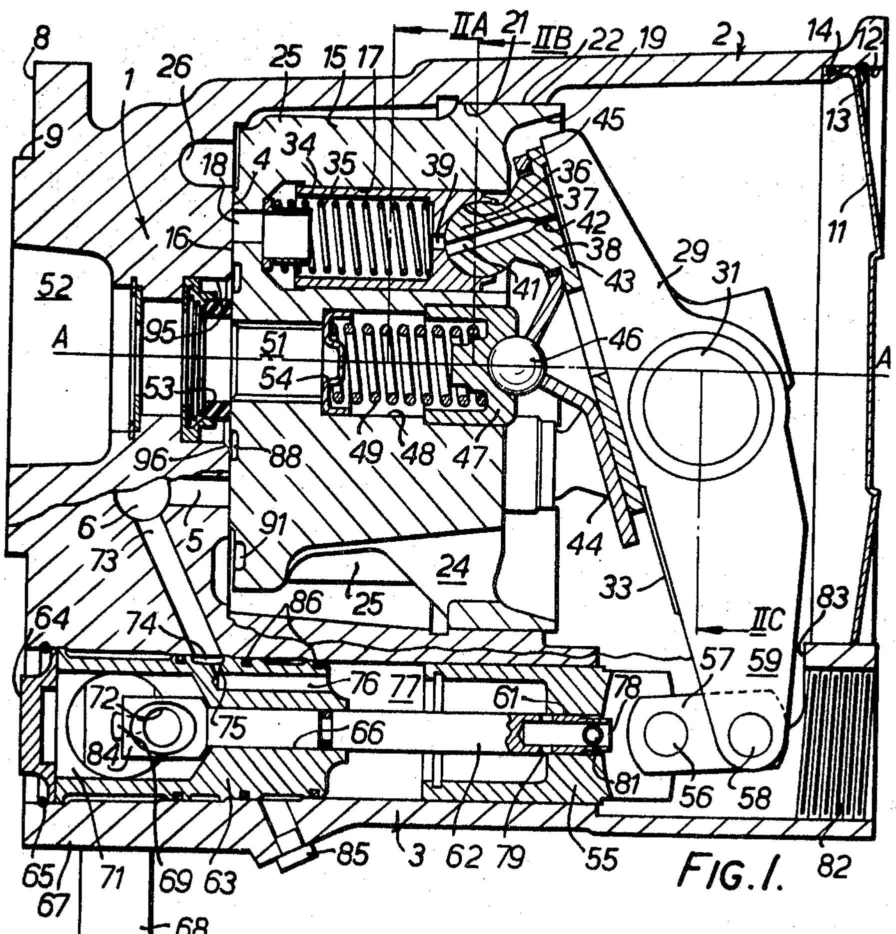


FIG. I.

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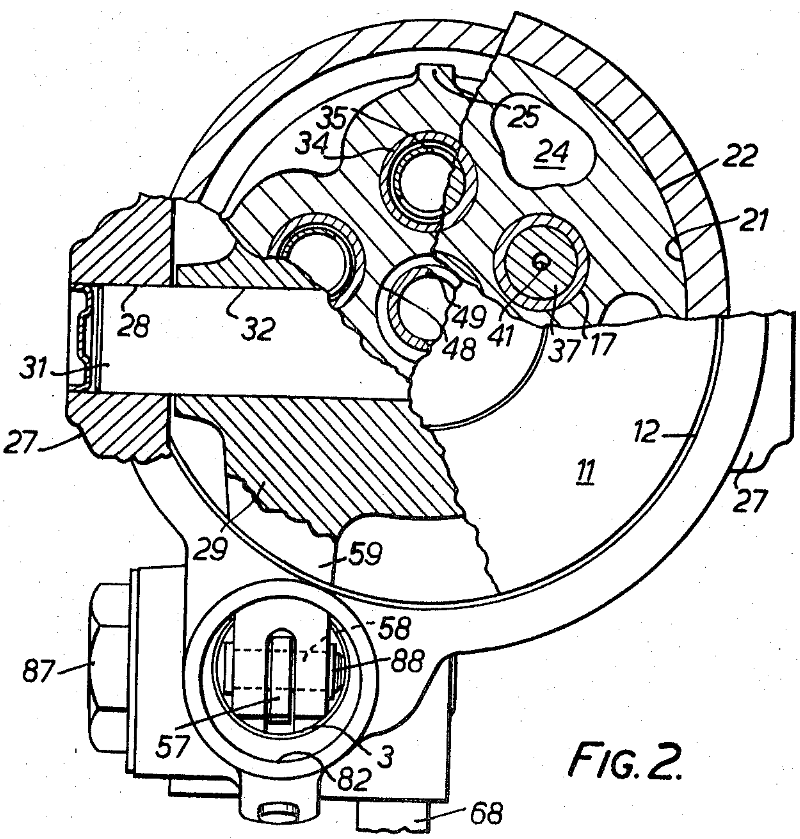

FIG. 2.

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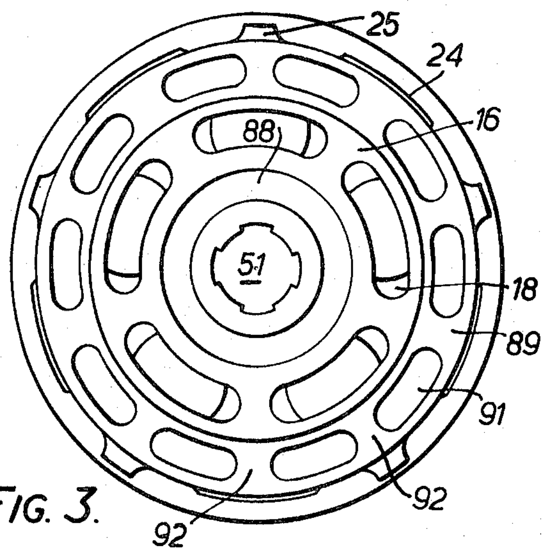

FIG. 3.

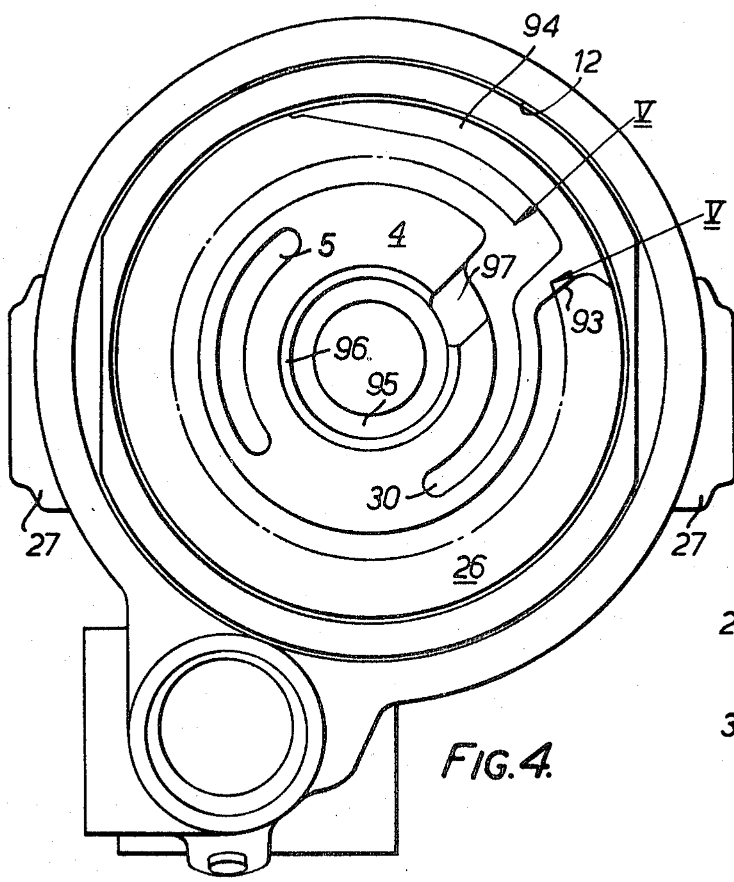

FIG. 4.

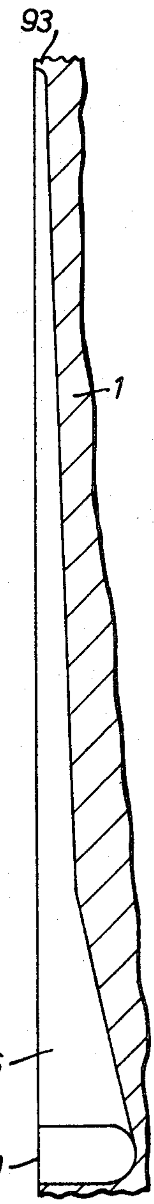

FIG. 5.

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SWASH PLATE DEVICE

The present invention concerns a swashplate device comprising a rotary cylinder block having a plurality of cylinders either parallel to or inclined to the rotation axis, a swashplate adjacent to one end of the cylinder block, pistons in the cylinders reciprocable during block rotation by engagement either directly or indirectly through slippers with the swashplate, a valve means having a flat valve surface at the end of the cylinder block remote from the swashplate to engage a flat block surface at that end of the block, high and low-pressure ports in said valve surface cooperating with cylinder ports opening into the flat block surface, an aperture in the valve means to accommodate a drive shaft for the cylinder block, and a seal acting between the valve means and the cylinder block around the aperture radially inwards of said ports. In the swashplate device as described above the function of the seal during operation is to prevent leakage of liquid into the aperture from the valve and block surfaces. Whilst the seal is effective to prevent such leakage it is possible in practice for the rotary action of the cylinder block to generate a suction zone around the seal which causes air to be drawn into the swashplate device from the aperture. The presence of such air in the hydraulic working liquid can adversely effect the operation of the swashplate device and any other hydraulic device to which it is connected.

The object of the present invention is to provide a swashplate device as described which will reduce the possibility of entry of air into the swashplate device over the said seal.

In accordance with the present invention the swashplate device described above includes a circular groove formed between the seal and the ports in at least one of the flat surfaces and a connection within the valve means from said groove to the said low-pressure port.

Centrifugal means driven by the said cylinder block may be provided to raise the pressure of liquid in the inlet port and in the said circular groove.

Alternatively or additionally an inlet groove may at least partially surround the valve surface to feed liquid to the inlet port, and impeller means driven by the cylinder block may rotate over the groove to urge liquid into the inlet port to raise pressure in both the inlet port and the said circular groove.

DESCRIPTION OF THE DRAWINGS

One embodiment of the invention for use as a pump will now be particularly described with reference to the accompanying drawings, in which

FIG. 1 is a cross section through the pump,

FIG. 2 is a composite elevation and cross section showing in part an elevation of the pump and the part sections on the lines IIA, IIB and IIC of FIG. 1,

FIG. 3 is an elevation of the end surface of the cylinder block containing the cylinder ports,

FIG. 4 is an elevation of the structural member showing in particular the flat valve surface, and

FIG. 5 is a developed cross section taken on the circular line V—V in FIG. 4.

In the drawings the structural member of the pump is an aluminum casting and it comprises three integrally formed parts indicated as the valve 1, the casing 2 and the servo cylinder 3. The valve 1 has a flat valve surface 4 which contains a high-pressure delivery port 5 of conventional kidney shape connected to a delivery passage 6 which terminates as a screw-threaded connection (not shown) on the outside of the valve 1. A plurality of mounting lugs 8 are provided around the periphery of the valve 1 for securing the pump in its operative position, the pump being correctly located by a cylindrical boss 9 adapted to fit in a corresponding hole on a driving motor or engine. The hollow casing 2 is closed at the end remote from the valve 1 by means of a cover 11 of pressed sheet metal secured in a large circular recess 12 by means of a circlip 13. A rubber seal 14 ensures a liquidtight connection between the casing 2 and the cover 11.

In the casing 2 a cylinder block 15 of cast iron is arranged for rotation about the axis A—A. The cylinder block 15 includes a flat surface 16 bearing against the valve surface 4. Within the block there are five regularly spaced cylinders 17 all of whose axes are parallel to the rotation axis A—A of the block. Each cylinder 17 includes a cylinder port 18 opening into the surface 16, the ports 18 being arranged to cooperate with the main pressure port 5 during rotation of the cylinder block 15. At a position remote from the surface 16, the cylinder block includes an integrally formed skirt 19 around which is formed a cylindrical bearing surface 21 which effectively surrounds the cylinder block. Within the casing 2 adjacent to the cylindrical bearing surface 21 an internal cylindrical bearing surface 22 is formed which directly engages the cylindrical bearing surface 21 of the block to locate the block for rotation.

Five passages 24 are formed within the cylinder block one between each adjacent pair of cylinders. Each passage opens from the surface of the block remote from the valve surface 4 between the radially directed vanes 25 formed on the cylinder block 15 within the casing 2. A groove 26 is formed in the valve around the valve surface 4, one end of this groove connecting to the low-pressure arcuate inlet port 30 formed in the valve surface 4.

The casing 2 remote from the valve includes a pair of integrally formed bosses 27 bored transversely to produce a pair of spaced apertures 28. Between the bosses 27 a swash plate 29 is mounted on a shaft 31 by means of a cylindrical bore 32 extending through the swashplate. The swashplate includes a flat swash surface 33 facing the cylinder block 15. Within each cylinder 17 a piston 34 and a compression spring 35 are located, the spring acting to urge its piston outwardly from the cylinder. At its outer end each piston 34 is formed with a spherical socket 36 into which a ball 37 is secured. The ball 37 is integrally connected to a slipper 38 engaging the swash surface 33. A hydraulic passage 39 within each piston 34 gives access to the socket 36 for lubrication and also connects to passage 41 in the ball which feeds at pressure through a restrictor 42 to a recess 43 in the slipper surface in contact with the swash surface 33. The recess is conventionally arranged so that hydraulic pressure acting in the recess will almost completely balance the hydraulic load acting on the piston.

A retaining plate 44 includes five apertures 45 engaged one on each slipper 38. Centrally the retaining plate 44 reacts against a ball 46 carried by a pad 47 slidably mounted in a central bore in the cylinder block, a compression spring 49 reacting between the block 15 and the pad 47 and serving simultaneously to urge the block against the valve surface 4 and to urge the retaining plate 44 to maintain the slippers in contact with the swash surface.

A splined aperture 51 is provided centrally within the cylinder block to open into a comparatively large aperture 52 extending through the valve 1. A drive shaft (not shown) may be inserted through the aperture 52 to engage the splined aperture to drive the cylinder block. A seal 53 may engage between the valve and the cylinder block in the manner disclosed in our copending application No. 32109/68, U.S. Ser. No. 838607. To prevent hydraulic leakage between the bore 48 and the aperture 52 the bore 48 is sealingly closed by means of a plug 54.

The servo cylinder 3 has a servo piston 55 slidably mounted therein one end being connected by means of a pivot pin 56 to a link 57 which in turn is connected by by a pivot pin 58 to a lever 59 extending from the swashplate 29. In FIG. 1 the swash plate is shown at a position of maximum inclination and the servo piston 55 is in a corresponding position.

The small diameter bore 61 within the piston 55 receives one end of a rod 62 which extends from the end of the servo cylinder 3 adjacent to the valve 1. The end of the cylinder 3 adjacent to the valve 1 has a plug 63 inserted therein being retained in position by a cap 64 and circlip 65. A central bore 66 through the plug 63 locates the rod 62 for sliding movement, a suitable seal on the rod **62** preventing leakage of liquid. The end of the cylinder **3** adjacent to the valve **1** is formed in an extension **67** from the valve **1** but integral therewith. A rotary controlled spindle **68** is suitably mounted in bearings in the extension **67**, the spindle **68** carrying a lever **69** which extends into a chamber **71** within the plug **63** to engage in a recess **72** in the end of the rod **62** such that rotation of the spindle **68** will cause endwise movement of the rod **62**. A passage **73** extends in the valve **1** from the delivery passage **6** to intersect the cylinder bore **3**. At the position of intersection the plug **63** includes a peripheral groove **74** from which a small hole is bored to form the restrictor **75** which connects through passage **76** in plug **63** to the working space **77** between the plug **63** and the piston **55**.

The end of the rod **62** includes a counter bore **78** from which a pair of radially directed control ports **79** open into the working space **77**. The rod **62** is located for limited motion within the piston bore **61** by means of a transverse pin **81** loosely engaging a transverse hole in the rod **62**. The movement permitted for the rod **62** relative to the piston will vary the opening of the port **79** over the edge of the bore **61** into the working space **77**. The ports **79** and the cooperating edge of the bore **61** form a variable restrictor adjustable by movement of rod **62**.

The end of the servo bore **3** opposite to the valve **1** is formed as a screw-threaded inlet connection **82** and liquid entering connection **82** may pass into the casing through a cutaway portion **83** through which the lever **59** extends to the link **57**. The liquid entering the pump thereby flows firstly over the swashplate **29** before entering the passages **24**.

FIG. 3 of the accompanying drawings shows the flat end surface **16** of the cylinder block in elevation. The splined central hole **51** is surrounded by the flat block surface **16** which contains the cylinder ports **18**, the flat surface **16** being interrupted by a coaxial circular groove **88** radially located in between the aperture **51** and the cylinder ports **18**. The surface **16** is surrounded by an annular flat surface **89** parallel to but slightly lower than the flat surface **16**. The annular surface **89** includes a plurality of shallow recesses **91** which define between them the axially extending vanes **92** for propelling liquid.

The annular surface **89** fits over the groove **26** (FIG. 4) formed around the flat valve surface **4**. The groove **26** is closed by a wall **93** which extends from the valve surface **4** across the groove **26** and connects to a land **94** to reduce the width of the groove **26** at the end portion thereof adjacent the wall. The groove **26** at its narrowed portion connects to one end of the low-pressure inlet port **30**. As seen in FIG. 5 the groove **26** starts at a shallow depth at the wall **93** and gradually increases in depth around the valve surface **4**, maximum depth of the groove being obtained at the position of entry to the inlet port **30**. The narrowed part of groove **26** adjacent to the land **94** increases more greatly in depth than the remainder of the groove **26**.

The seal **53** is seated in an annular recess **95** formed in the center of the valve **1** so that the seal **53** can engage the flat portion of the block surface **16** between the central aperture **51** and groove **88**. The outer edge of the recess **95** is chamfered at **96** so that a portion of the recess **95** radially outwards of the seal **53** makes connection with the annular groove **88** in the cylinder block surface **16**. A shallow channel **97** in the valve surface **4** connects from the recess **95** into the inlet port **30** whereby liquid at low pressure built up in the inlet port **30** may enter the recess **95** around the seal **53** to retain a low backing pressure at the seal **53** to help to prevent induction of air from the aperture **52** across the seal and into the pump.

In operation the cylinder block is rotatably driven by a drive shaft inserted through the aperture **52** into the cylinder block and rotation of the cylinder block causes reciprocation of the pistons in the cylinders by virtue of the fact that the slippers are held by springs **35** and **49** against the swashplate surface. During rotation liquid fed from the inlet connection **82** flows around the swashplate and into the passages **24** there being induced by centrifugal pumping action to flow to the groove **26**. The rotation of the cylinder block surface **89** over the groove **26** will by virtue of the vanes **92** induce flow of liquid around the groove **26** and into the inlet port **30**. The vanes **92** acting on the liquid in the groove **26** will do so by virtue of the viscosity of liquid and it will be appreciated that the actual velocity of liquid flowing around the groove **26** will be considerably lower than the velocity of the cylinder block over the groove even when the pistons have their maximum stroke.

The total pressure buildup at the inlet port **30** therefore results from the centrifuging action of the passages **24** and vanes **25** of the cylinder block and further from the impelling action of the vanes **92** on liquid in groove **26** by virtue of the viscosity of the liquid. The pressure of liquid in the inlet port **30** whilst still comparatively low will nevertheless provide an adequate boost pressure to assist the entry of liquid into the cylinders **17** during outward movement of the pistons **34**. It will be understood that for the direction of rotation of the cylinder block, pistons in cylinders connected to the inlet port **30** will be moving outwardly from their cylinders while pistons in cylinders connected to the delivery port **5** will be moving into their cylinders to compress the liquid and deliver it to the port **5**.

During rotation of the cylinder block there is a tendency for a reduced pressure to be developed in the recess **95** around the seal **53** due to centrifuging action of the cylinder block on the liquid. The channel **97** which connects the inlet port **30** to the recess **95** supplies liquid at the pressure in the inlet port **30** to the recess **95** and will increase the pressure in the recess to a small extent and prevent the tendency for air to be induced to enter into the pump between the seal **53** and the cylinder block surface **16**.

The fact that the swashplate is inclined causes considerable side thrust to be exerted on the cylinder block through the pistons and the axial extend of the bearing surfaces **21** and **22** is such that the line of action of side force exerted on the pistons by the swashplate will pass directly through the bearing surfaces without creating tilting movement of the cylinder block. The flow of liquid through the passages **24** will assist in cooling the bearing surfaces **21** and **22**.

The offset relation of the shaft **31** having regard to the rotation axis A—A of the cylinder block results in a torque being generated on the swashplate **29** about the axis of shaft **31** which will tend to reduce the inclination of the swashplate to zero, the limit of such movement being the engagement of head **84** of rod **62** against the cap **64**. Maximum inclination of the swashplate is limited by the engagement of the head **84** against the end of chamber **71** opposite to the cap **64**. The required angular setting for the swashplate is selected by the spindle **68** which adjusts the axial position of the rod **62**. Movement of the rod **62** will adjust the variable restrictor formed by port **79** to control the pressure developed within the working space **77** by virtue of the series connection of the fixed restrictor **75** with the variable restrictor between the high pressure connection **76** and the low pressure interiorly of the casing **2**. The pressure within the working space **77** urges the swash plate towards its maximum inclination while the torque developed on the swashplate itself urges it to the minimum inclination. Simple adjustment of the spindle **68** will therefore control pressure in the working space **77** to cause the swashplate to take up an angular position which is in proportion to the angular setting of the spindle **68**.

During manufacture the passage **73** is formed by drilling from the exterior of the casing and in use the plug **85** closes the outer end of the passage **73**. The passage **73** connects high pressure only to the groove **74** of plug **63**.

The grade of aluminum alloy selected for the structural member forming the casing, the valve, the bosses and the servo cylinder is chosen to have the necessary strength to cater for the intended operating pressures of the pump. The design of the ports **5** and **30** in the valve in combination with the cross-sectional areas of the pistons is such that the cylinder block in operation presses only very lightly against the valve surface 4, the principle force holding the block on this surface being that provided by the springs **35** and **49**. During rotation of the cylinder block the centrifugal pressure of liquid developed around the cylinder block and the further pressure of liquid built up in the groove **26** particularly in the narrow part thereof adjacent to land **94** produce a force on the cylinder block dependent on speed which operates against the loading applied by the springs **45** and **39** and when the pump is driven in excess of a predetermined speed causes the cylinder block to lift away from the valve surface **4** to reduce the pumping effect and also to increase flow of liquid over the valve surface **4** to provide better lubrication. A protection is thus offered against damage to the valve surfaces due to "-pickup" when the pump is driven at high speeds.

The described embodiment is intended for use as a pump but a motor is also within the scope of the present invention.

I claim:

1. A swashplate device comprising a rotary cylinder block having a plurality of cylinders either parallel to or inclined to the rotation axis, a swashplate adjacent to one end of the cylinder block, pistons in the cylinders reciprocable during block rotation by engagement either directly or indirectly through slippers with the swashplate, a valve means having a flat valve surface at the end of the cylinder block remote from the swashplate to engage a flat block surface at that end of the block, high and low-pressure ports in the said valve surface cooperating with cylinder ports opening into the said block surface, boost pump means to supply liquid at low pressure to said low-pressure port, an aperture in the valve to accommodate a drive shaft for the cylinder block, a seal acting between the valve means and the cylinder block around the aperture radially inwards of said ports, a circular groove formed between the seal and the ports in at least one of the flat surfaces, and a connection within the valve means from the said groove to the said low-pressure port.

2. A swashplate device as claimed in claim **1** including centrifugal means driven by said cylinder block.

3. A swashplate device as claimed in claim **1** including an inlet groove at least partially around the valve surface and adapted to feed liquid to the inlet port, and impeller means driven by the block rotating over the groove to urge liquid into the inlet port and to raise liquid pressure in the inlet port and the said circular groove.

4. A swashplate device as claimed in claim **1** wherein the said circular groove is formed in the flat end surface of the cylinder block and the connection to the inlet port comprises a connecting groove in the valve surface extending from the inlet port to a position overlapping the said circular groove.

5. A swashplate device as claimed in claim **1** including a recess in the valve opening into the valve surface and containing the seal, a circular space being provided in the recess around the seal to form a circular groove in the valve surface from which the said connecting groove extends to the inlet port.

6. A swashplate device as claimed in claim **1** including an inlet groove at least partially around the valve surface adapted to feed liquid to the inlet port, an impeller device driven by the block rotating over the groove to urge liquid into the inlet port to raise pressure in both inlet port and said circular port, and centrifugal means driven by said cylinder block to raise the pressure of liquid in said inlet groove whereby the pressure of liquid in the inlet port and the circular groove is raised by pumping action at both the inlet groove and the centrifugal means.

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