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(54) Axial piston pump.

(57) An axial piston pump comprises a drive shaft (2), a cylinder block (4) rotatable with the drive shaft (2), a plurality of pistons (6a-6i) provided within the cylinder block (4), a swashplate (12) situated at one axial end of the cylinder block (4) for causing reciprocation of the pistons (6a-6i) when the said cylinder block (4) is rotated, and a valve plate (26) situated at a second axial end of the cylinder block (4); wherein either one of the cylinder block (4) or valve plate (26) is urged against the other to form a hydrostatic seal between the cylinder block (4) and a face (52) of the said valve plate (26). The pump may be characterised by one or both of the following features :-

A spiral groove bearing (50) is provided between the valve plate (26) and the cylinder block (4).

The valve plate (26) is urged against the cylinder block (4) by means of a second piston (60) which has an arcuate load face.

Additionally, an axial piston pump comprises a drive shaft (2), a cylinder block (4) rotatable with the drive shaft (2), a plurality of pistons (6a-6i) provided within the cylinder block (4), a swashplate (12) situated at one axial end of the cylinder block (4) for causing reciprocation of the pistons (6a-6i) when the cylinder block (4) is rotated; the said swashplate (12) being provided with a curved back, the curved back being seated within a curved recess in a swashplate cradle (14), a hydrostatic bearing (70, 72) being formed between the said curved back of the swashplate (12) and the curved recess of the swashplate cradle (14), and the said swashplate (12) being capable of swivelling within the said recess; wherein high pressure oil is supplied to the said hydrostatic bearing (70,72) via a passage provided in at least one of the said pistons and via a hole (80) provided in the body of the said swashplate (12).

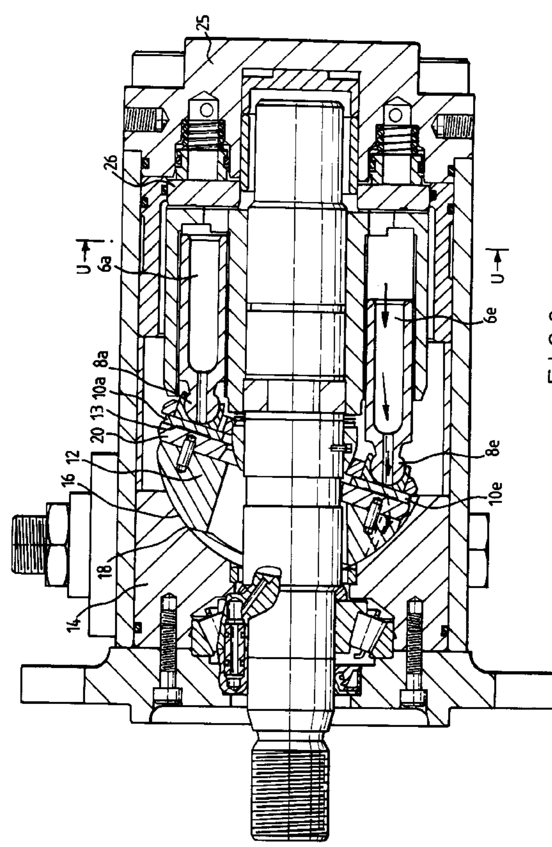

FIG.2

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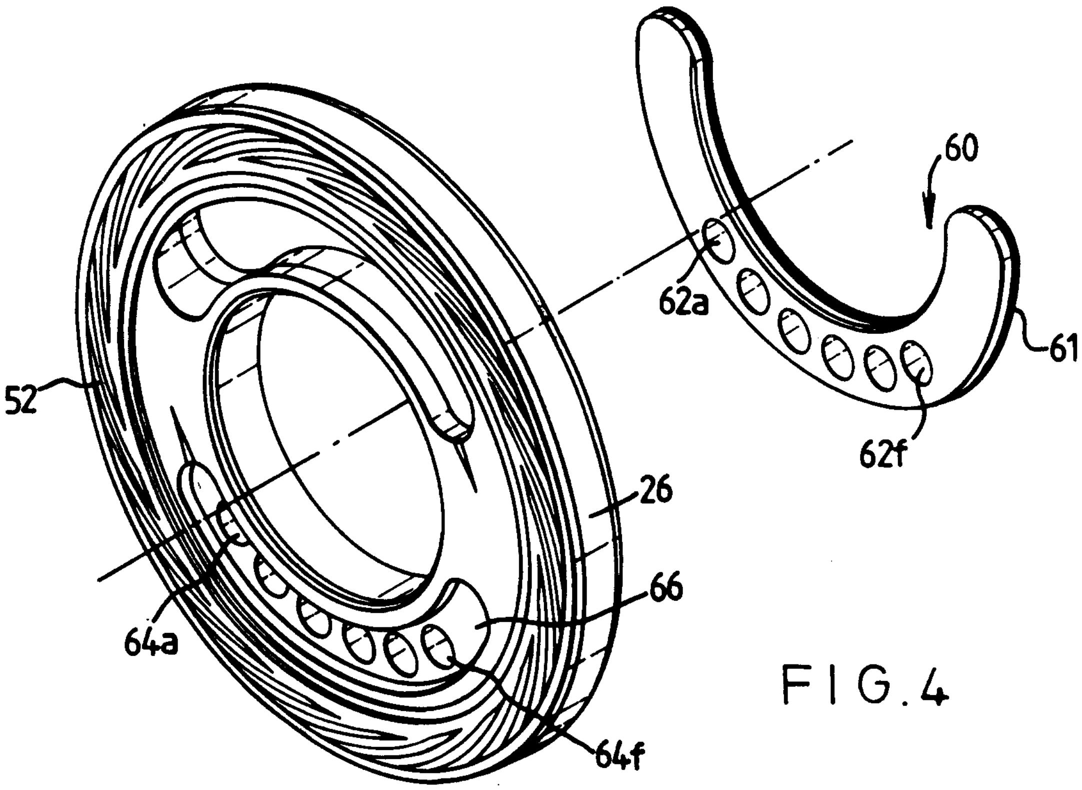

FIG.4

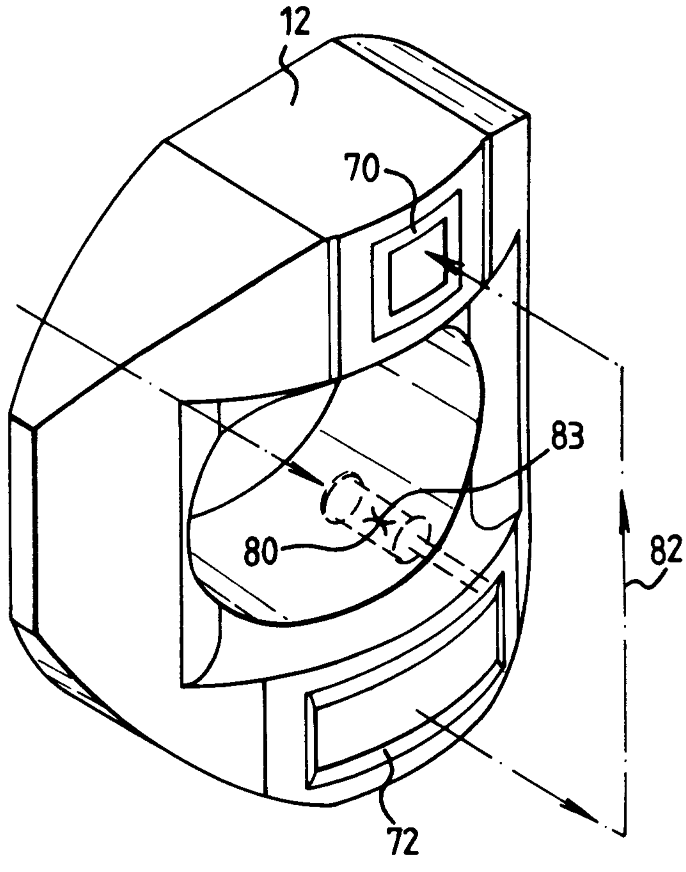

FIG.5

The present invention relates to an axial piston pump of the type generally used in hydraulic systems.

A conventional axial piston pump comprises a rotating cylinder block which is supported on a drive shaft which is, in turn, supported on bearings, to enable the shaft and cylinder block to rotate together. The block contains a plurality of pistons. Each piston is fitted, by means of a universal joint, with a slipper pad. The slipper pads contact and react against a load surface of a swashplate which surrounds the drive shaft. The load surface is inclined at an angle to the axis of rotation of the drive shaft.

The swashplate is held stationary in relation to the rotating cylinder block. Therefore, the action of the slipper pads against the angled load face of the swashplate causes a reciprocating action in the pistons.

The reciprocation of the pistons causes oil to be drawn into the cylinder via an inlet port located in the pump housing, a kidney-shaped inlet port situated in a valve plate located between the cover and an opposed, adjacent valve face of the cylinder block. The valve face of the cylinder block and the opposed face of the valve plate lie in a plane perpendicular to the rotational axis of the drive shaft.

The oil is discharged via slots in the valve face of the cylinder block and on through a kidney-shaped outlet port in the valve plate. This discharged oil is subsequently directed through loading pistons housed within the cover and finally on through an outlet port provided in the cover.

The pump design must ensure that clearance between valve plate and cylinder block face is controlled in order to minimise leakage without incurring excessive frictional losses.

This controlled clearance can be achieved in two ways. The first method has the valve plate rigidly mounted to the pump casing with the cylinder block connected to the drive shaft by a loose fitting spline. The main pumping pistons load the cylinder block hydrostatically against the valve plate. The clearance in the spline allows the cylinder block to articulate, thus accommodating manufacturing tolerances and deflections arising from the loads generated within the pump. This articulation facilitates the alignment of the cylinder block valve face and the valve plate. Such a conventional pump is shown in accompanying figures 7a and 7b.

The second configuration has the cylinder block rigidly mounted to the drive shaft and the valve plate is floating in the axial direction. The valve plate is loaded against the cylinder block by a series of loading pistons. The second arrangement affords the advantage that the low inertia valve plate can follow the cylinder block runnout with minimum vibration. The higher inertia of the floating cylinder block version leads to high amplitude vibrations and consequently the valve plate clearance in adversely affected.

The subsequent technical description within this specification deals with the floating valve plate pump, although it is to be understood that the invention is not limited for use with only such pumps.

In a floating valve plate pump, the loading pistons are used to load the valve plate onto the cylinder block in the axial direction of the shaft and are designed to prevent separation of the porting interface valve face, thereby minimising a loss of pressurized fluid into the pump casing.

The displacement of the pump can be varied from zero to a maximum by altering the angle of the swashplate using, for example, control pistons situated within the pump housing. The control system, for controlling the angle of the swashplate, requires that the friction between a rear, curved side of the swashplate and a complementary, but inversely, curved swashplate cradle (which seats the swashplate) be kept to a minimum. This can be achieved by means of a hydrostatic bearing system which is supplied with lubricating oil at a pump outlet pressure. Alternatively, a roller bearing can be used, but this feature has the disadvantages of high cost, increased noise level and limited life.

Although such pumps have been widely used, they do have short-comings related to efficiency, reliability and cost which the invention addresses.

The valve plate provides a mechanism for transferring fluid to and from the cylinder block. It is important to maintain the design clearance between the valve plate and cylinder block in order to optimize leakage and frictional losses. If loading is excessive, it results in seizure between the static valve plate and the rotating cylinder block.

To date, the valve plate has been loaded against the cylinder block by four (for example) circular loading pistons. Each of the discrete pistons imparts a localised load onto the valve plate. This results in distortion of the valve plate, leading to undesirable variation in the clearance between the valve plate and the cylinder block and in the extreme, metal to metal contact can occur. In areas of high clearance leakage increases and the pump's efficiency is reduced. Areas of low clearance increase the risk of seizure and the pump's reliability is adversely affected at extreme operating conditions.

The conventional way of providing the hydrostatic low friction bearing between the rear of the swashplate and the swashplate cradle requires a feed of high pressure oil from the pump outlet port. This has conventionally been achieved by means of a series of interconnecting drillings from the outlet port at one end of the pump, via the pump casing, to the swashplate bearing which is at the opposite end of the pump to the outlet port. The drilling provided in the pump casing is complicated and relatively expensive to manufacture.

The present invention sets out to provide an axial piston pump in which the leakage gap between the cylinder block and the valve plate is minimised but without causing seizure or excessive frictional losses.

Furthermore, the invention sets out to provide an arrangement in which distortion of the valve plate is obviated or mitigated, thereby avoiding local variations in the thickness of the oil film between the valve plate and the cylinder block.

Additionally, the invention sets out to provide an arrangement in which oil can be supplied to a hydrostatic bearing provided between the swashplate and the swashplate cradle, but without requiring a complicated drilling of the pump casing.

According to a first aspect of the invention there is provided an axial piston pump comprising a drive shaft, a cylinder block rotatable with the drive shaft, a plurality of pistons provided within the cylinder block, a swashplate situated at one axial end of the cylinder block for causing reciprocation of the pistons when the said cylinder block is rotated, and a valve plate situated at a second axial end of the cylinder block; wherein either one of the cylinder block or valve plate is urged against the other to form a hydrostatic seal between the cylinder block and a face of the said valve plate; characterised in that a spiral groove bearing is provided between the valve plate and the cylinder block.

In a preferred embodiment the cylinder block is fixed relative to the axial direction of the drive shaft and the valve plate is urged against the cylinder block.

Alternatively, the valve plate can be fixed in the axial direction of the drive shaft and the cylinder block urged against it.

Preferably, the spiral groove bearing will be provided in the valve plate. It can be formed by a plurality of spirally orientated grooves. Alternatively, the grooves can be straight. If preferred, the spiral groove bearing can be provided in the cylinder block.

The grooves of the spiral groove bearing can be very shallow.

According to a second aspect of the invention there is provided an axial piston pump comprising a drive shaft, a cylinder block rotatable with the drive shaft, a plurality of first pistons provided within the cylinder block, a swashplate situated at one axial end of the cylinder block for causing reciprocation of the pistons when the said cylinder block is rotated, a valve plate situated at a second axial end of the cylinder block and held stationary relative to the direction of rotation of the cylinder block and urged against the said second end of the cylinder block to form a hydrostatic seal between the cylinder block and a face of the said valve plate, wherein the valve plate is urged against the cylinder block by means of a second piston. Characterised in that the second piston has an arcuate load face.

Preferably, the piston will be kidney-shaped.

According to a third aspect of the invention there is provided an axial piston pump comprising a drive shaft, a cylinder block rotatable with the drive shaft, a plurality of pistons provided within the cylinder block, a swashplate situated at one axial end of the cylinder block for causing reciprocation of the pistons when the cylinder block is rotated; the said swashplate being provided with a curved back, the curved back being seated within a curved recess in a swashplate cradle the said swashplate being capable of swivelling within the said recess; characterised in that a hydrostatic bearing is formed between the said curved back of the swashplate and the curved recess of the swashplate cradle, and high pressure oil is supplied to the said hydrostatic bearing via a passage provided in at least one of the said pistons and via a hole provided in the body of the said swashplate.

Preferably, a pair of hydrostatic bearings are provided between the swashplate back and the swashplate cradle. One of these may be fed directly by means of the said drilling in the swashplate and the other is fed via the first bearing and via a drilling provided in the body of the swashplate cradle, which links the two bearings together. A control orifice can be provided in the feed drilling in the swashplate to modulate the pressure at the hydrostatic bearings and minimise the leakage. Each of the pistons can comprise a hole for allowing oil to be fed to the swashplate.

In a preferred embodiment, the load surface of the swashplate is provided with a wear plate, upon which slippers, provided at the respective ends of the pistons, move. The slippers each comprise a drilling to allow oil to escape from their respective piston and the wearplate comprises a drilling which communicates with the drilling in the swashplate.

Embodiments of the invention will now be described by way of example and with reference to the accompanying drawings in which: -

Figure 1 is a section through a pump in accordance with the present invention;

Figure 2 is a section through Y-Y of the pump shown in Figure 1 and schematically showing a feed path for oil in accordance with the third aspect of the invention;

Figure 3 is an exploded perspective view showing a valve plate in accordance with a first aspect of the invention and in combination with four conventional loading pistons;

Figure 4 is a valve plate in accordance with the first aspect of the invention in combination with a loading piston according to a second aspect of the invention;

Figure 5 is a perspective view of a swashplate in accordance with a third aspect of the present invention;

Figure 6 is a perspective view of a cylinder block in accordance with the invention; and

Figures 7a and 7b are side and top views, respectively, of a conventional floating cylinder block type of axial piston pump.

The general construction of the pump according to the present invention is the same as that of the conventional pump described above.

As can be seen from Figures 1 and 2, the pump comprises a drive shaft 2 which is fitted with a cylinder block 4. The cylinder block 4 is keyed to the said drive shaft 2 by means of a portion 7 of the drive shaft 2 which is generally square in cross-section and fits within a similarly profiled recess in the cylinder block 4. The cylinder block 4 is fixed to the drive shaft 2 in such a manner that rotation of the drive shaft 2 causes the cylinder block 4 to rotate. The drive shaft is supported by bearings 3 and 5 to facilitate rotation. The cylinder block 4 is fitted with nine pistons 6a - 6i.

Each piston is reciprocally movable in a direction parallel to the axis of rotation of the cylinder block assembly. A ball 8a - 8e is provided at the end of each piston and is received within a socket in a respective slipper pad 10a - 10e.

A swashplate 12 is provided within a swashplate cradle 14. The swashplate 12 has a curved back 16, which is part-circular in profile. The swashplate cradle 14 is provided with a swashplate seating surface 18 which is curved to the same degree as the rear of the swashplate 16. This allows the swashplate to swivel within the swashplate cradle 14.

During use, the swashplate 12 will be positioned within the swashplate cradle 14 with its load face 20 inclined such that a normal to the load face 20 is at an angle with the rotational axis of the drive shaft 2.

The angle of inclination of the swashplate 12 can be adjusted by means of a pair of control pistons (not completely shown) which move an arm 24 which is received within the swashplate 12. The angle of inclination of the swashplate is adjusted by means of the control pistons 22 which move the arm, thereby moving the swashplate. The direction of movement of the pistons 22 is into and out of the page as seen in Figure 1.

The rotation of the cylinder block 4 causes the pistons 6a - 6i to reciprocate as the piston slippers 10a - 10i act against the load face of the swashplate 12.

A valve plate 26 is provided at the other end of the cylinder block 4.

The valve plate 26 is loaded against the valve face of the cylinder block by four loading pistons 30a-30d. These pistons 30a-30d serve to prevent separation of the valve plate from the cylinder block valve face, thus minimising the loss of pressurized fluid into the pump casing. Each piston is provided with a seal 31a-31d about its perimeter.

The valve plate is provided with a kidney-shaped inlet port 28 and two kidney-shaped outlet ports 29a and 29b.

A kidney-shaped recess is provided on the face 52 of the valve plate 26 which addresses the cylinder block. This recess communicates with the outlet ports 29a and 29b.

During use, reciprocation of the pistons causes oil to be drawn into the cylinder via the kidney-shaped inlet port 28 and the kidney-shaped slots 27a-27i in the valve face of the cylinder block. The oil is discharged via the kidney slots 27a-27i, the valve plate outlet ports 29a-29b, the loading pistons 30a-30d and finally an outlet port 25 in the cover.

In accordance with a first aspect of this invention, a spiral groove bearing 50 is provided in a peripheral region of the cylinder block facing face 52 of the valve plate 26.

The spiral groove bearing 50 is formed from a plurality of grooves 54, which are formed so as to spiral inwardly from the periphery of the cylinder block facing face 52 of the valve plate towards the centre of this face 52.

Because the valve plate is held stationary relative to the rotating cylinder block during use , oil is driven into the grooves of the spiral groove bearing 50 and creates a hydrodynamic pressure. This provides a self-compensating effect and significantly reduces the risk of seizure. This arrangement enables the valve plate 26 to be loaded more heavily, thereby reducing leakage.

In accordance with the second aspect of the invention the four conventional valve plate loading pistons 30a - 30d are replaced with a single kidney-shaped piston 60. This can be seen in Figure 4.

The piston 60 comprises six outlet apertures 62a - 62f. These are aligned with six similarly sized and shaped outlet apertures 64a - 64f provided in a single kidney-shaped outlet port 66 of the valve plate 26. During operation of the pump, oil can escape by means of the outlet apertures 64a - 64f and subsequently on out through the outlet apertures 62a - 62f in the piston 60. The kidney-shaped inlet port of the valve plate 26 is identical to that of the conventional valve plate 26.

The kidney shaped piston 60 is fitted with a seal 61 about its perimeter; this corresponds to the seals 31a-31d of the prior art loading pistons.

Preferably, the kidney-shaped piston 60 will be used in conjunction with a spiral groove bearing 50, but it will operate successfully without the presence of such a spiral groove bearing.

By adopting a single piston 60, the valve plate loading becomes evenly distributed, resulting in less distortion of the valve plate. As a result of this reduction in distortion of the valve plate, local distortions in the oil film thickness caused by using discrete pistons can be avoided, providing less leakage minimum friction and higher reliability. Because the valve plate distributes the loading more evenly, the valve plate is less susceptible to deformation and the thickness of the valve plate can be reduced. This means that costs can be saved.

If desired, the valve plate 26 plus loading piston 60 could be manufactured as a single integral component.

In order to facilitate adjustment of the swashplate 12 within the swashplate cradle 14, a pair of hydrostatic bearings 70 and 72 are provided in the curved surface 16 of the swashplate 12. This can best be seen from Figure 5. These bearings are fed with oil at pump outlet pressure.

The high pressure oil is supplied to the hydrostatic bearings 70 and 72 from the outlet port via openings provided in the nine pumping pistons 6a - 6i, through holes in the respective slipper pads 10a - 10i and via a feed hole 80 which extends through the wearplate 13 and the swashplate 12. The feed hole 80 directly feeds hydrostatic bearing 72. Hydrostatic bearing 70 is fed by means of a drilling 82 (shown in Figure 1 and schematically in Figure 5) in the swashplate cradle 14. Drilling 82 connects the two bearings 70 and 72. An orifice 83 is fitted in the drilling 80 to control the pressure at the bearings and limit the leakage rate.

The position of feed hole 80 relative to the outlet port will determine the pressure of the oil supplied to the bearings. For maximum pressure at the hydrostatic bearings 70, 72, the feed hole and outlet port would need to be aligned.

Each time a slipper pad passes across the feed hole 80 in the wearplate 13, a pulse of high pressure oil is fed to the hydrostatic bearings. This can be seen schematically in Figure 6.

This arrangement reduces the complexity of machining components to provide the oil supply and thereby reduces the cost of the pump. It also provides a self-cleaning action for the control orifice 83, reduces fiction between swashplate 12 and cradle 14 and minimises leakage.

The third aspect can be combined in a single pump along with one or more of the first and second aspect of the invention. Alternatively, the third aspect of the invention can be employed separately.

The first and third aspect of the invention can be used in a floating cylinder block pump described earlier. All three aspects of the invention could be incorporated in the hydraulic motor variant of the pump. When applying the arcuate loading piston principle to motors it will be necessary to provide two loading pistons, one adjacent to the supply port (equivalent to the pump's high pressure outlet port) and the second adjacent to the return port (equivalent to the pump's low pressure inlet port). The fitting of two pistons permits rotation in either the clockwise or anit-clockwise direction.

Upon making reference to the foregoing description, which is given by way of illustrative example only, many further modifications and adaptations will suggest themselves to those versed in the art. The scope of the present invention is not intended to be limited to exclude such modifications and adaptations.

Claims

1. An axial piston pump comprising a drive shaft (2), a cylinder block (4) rotatable with the drive shaft (2), a plurality of pistons (6a-6i) provided within the cylinder block (4), a swashplate (12) situated at one axial end of the cylinder block (4) for causing reciprocation of the pistons (6a-6i) when the said cylinder block (4) is rotated, and a valve plate (26) situated at a second axial end of the cylinder block (4); wherein either one of the cylinder block (4) or valve plate (26) is urged against the other to form a hydrostatic seal between the cylinder block (4) and a face (52) of the said valve plate (26); characterised in that a spiral groove bearing (50) is provided between the valve plate (26) and the cylinder block (4).

2. An axial piston pump according to Claim 1, wherein the cylinder block (4) is fixed relative to the axial direction of the drive shaft (2) and the valve plate (26) is urged aginst the cylinder block (4).

3. An axial piston pump according to Claim 1, wherein the valve plate (26) is fixed in the axial direction of the drive shaft (2) and the cylinder block (4) is urged against the valve plate (26).

4. An axial piston pump according to any preceding Claim, wherein grooves (54) of the spiral groove bearing (50) are provided in the valve plate (26).

5. An axial piston pump according to Claim 1, 2 or 3, wherein grooves of the spiral groove bearing (50) are provided in the cylinder block (4).

6. An axial piston pump according to any preceding Claim, wherein the spiral groove bearing (50) comprises a plurality of spirally configured grooves.

7. An axial piston pump according to any one of Claims 1 to 5, wherein the spiral groove bearing is formed from a plurality of straight grooves.

8. An axial piston pump according to any preceding Claim, wherein the grooves (54) forming the spiral groove bearing (50) are very shallow.

9. An axial piston pump comprising a drive shaft (2), a cylinder block (4) rotatable with the drive shaft

(2), a plurality of first pistons (6a-6i) provided within the cylinder block (4), a swashplate (12) situated at one axial end of the cylinder block (4) for causing reciprocation of the pistons (6a-6i) when the said cylinder block (4) is rotated, a valve plate (26) situated at a second axial end of the cylinder block (4) and held stationary relative to the direction of rotation of the cylinder block (4) and urged against the said second end of the cylinder block (4) to form a hydrostatic seal between the cylinder block (4) and a face (52) of the said valve plate (26), wherein the valve plate (26) is urged against the cylinder block (4) by means of a second piston (60) characterised in that the second piston (60) has an arcuate load face.

10. An axial piston pump according to Claim 9, wherein the second piston (60) has a kidney-shaped load face.

11. An axial piston pump according to Claim 9 or 10, wherein the second piston (60) comprises a plurality of outlet apertures (62a-62f); each aperture (62a-62f) being aligned with a respective similarly configured outlet aperture (64a-64f) in the valve plate (26).

12. An axial piston pump according to any one of Claims 9 to 11, wherein the valve plate (26) and second piston (60) are integrally formed.

13. An axial piston pump comprising a drive shaft (2), a cylinder block (4) rotatable with the drive shaft (2), a plurality of pistons (6a-6i) provided within the cylinder block (4), a swashplate (12) situated at one axial end of the cylinder block (4) for causing reciprocation of the pistons (6a-6i) when the cylinder block (4) is rotated; the said swashplate (12) being provided with a curved back, the curved back being seated within a curved recess in a swashplate cradle (14), the said swashplate (12) being capable of swivelling within the said recess (14); characterised in that a hydrostatic bearing (70,72) is formed between the said curved back of the swashplate (12) and the curved recess of the swashplate cradle (14), and high pressure oil is supplied to the said hydrostatic bearing (70,72) via a passage provided in at least one of the said pistons and via a hole (80) provided in the body of the said swashplate (12).

14. An axial piston pump according to Claim 13, wherein a pair of hydrostatic bearings (70, 72) are provided between the swashplate back and the swashplate cradle.

15. An axial piston pump according to Claim 14, wherein a first of the hydrostatic bearings (72) is fed directly by means of the said hole (80) provided in the swashplate (12), and the other (70) is fed via the first hydrostatic bearing (72) and via a passage (82) provided in the body of the swashplate cradle (14), which passage (82) links the two bearings (70, 72).

16. An axial piston pump according to any one of Claims 13 to 15, further comprising a control orifice (83) provided in the said hole (80) in the swashplate (12) for modulating the pressure at the hydrostatic bearing or bearings (70,72).

17. An axial piston pump according to any one of Claims 13 to 16, wherein each of the said pistons (6a-6i) comprises a hole for allowing oil to be fed to the swashplate (12).

18. An axial piston pump according to Claim 17, wherein the load surface of the swashplate is provided with a wear plate (13) upon which slippers (10a-10i), provided at the respective ends of the pistons (6a-6i) move; each slipper (10a-10i) comprising a passage to allow oil to escape from its respective piston (6a-6i), and the wear plate (13) comprising a passage which communicates with the hole (80) in the swashplate (12).

19. An axial piston pump substantially as herein described with reference to figures 1, 2 and 3, 4, 5 or 6 of the accompanying drawings.

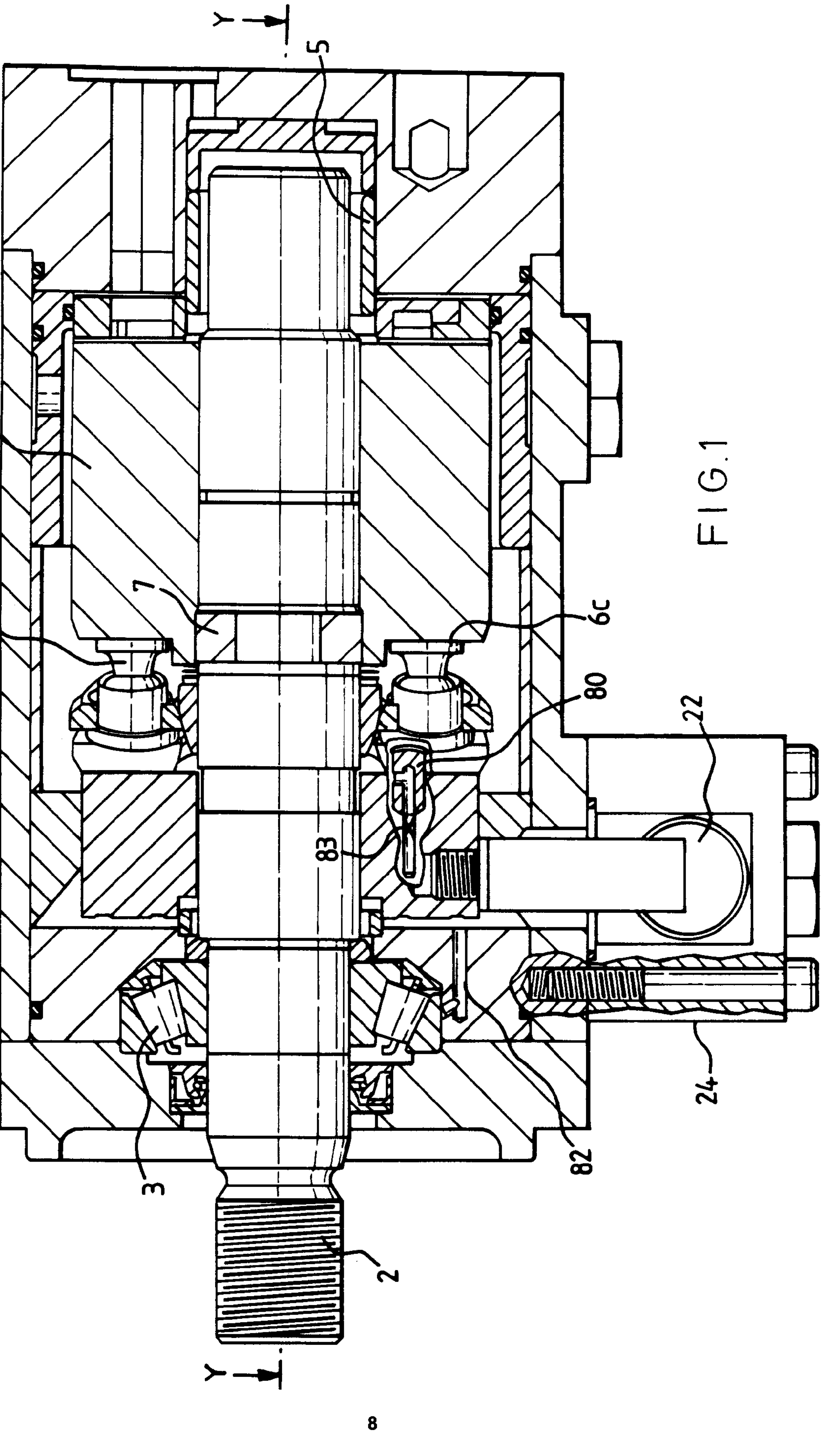

FIG.1

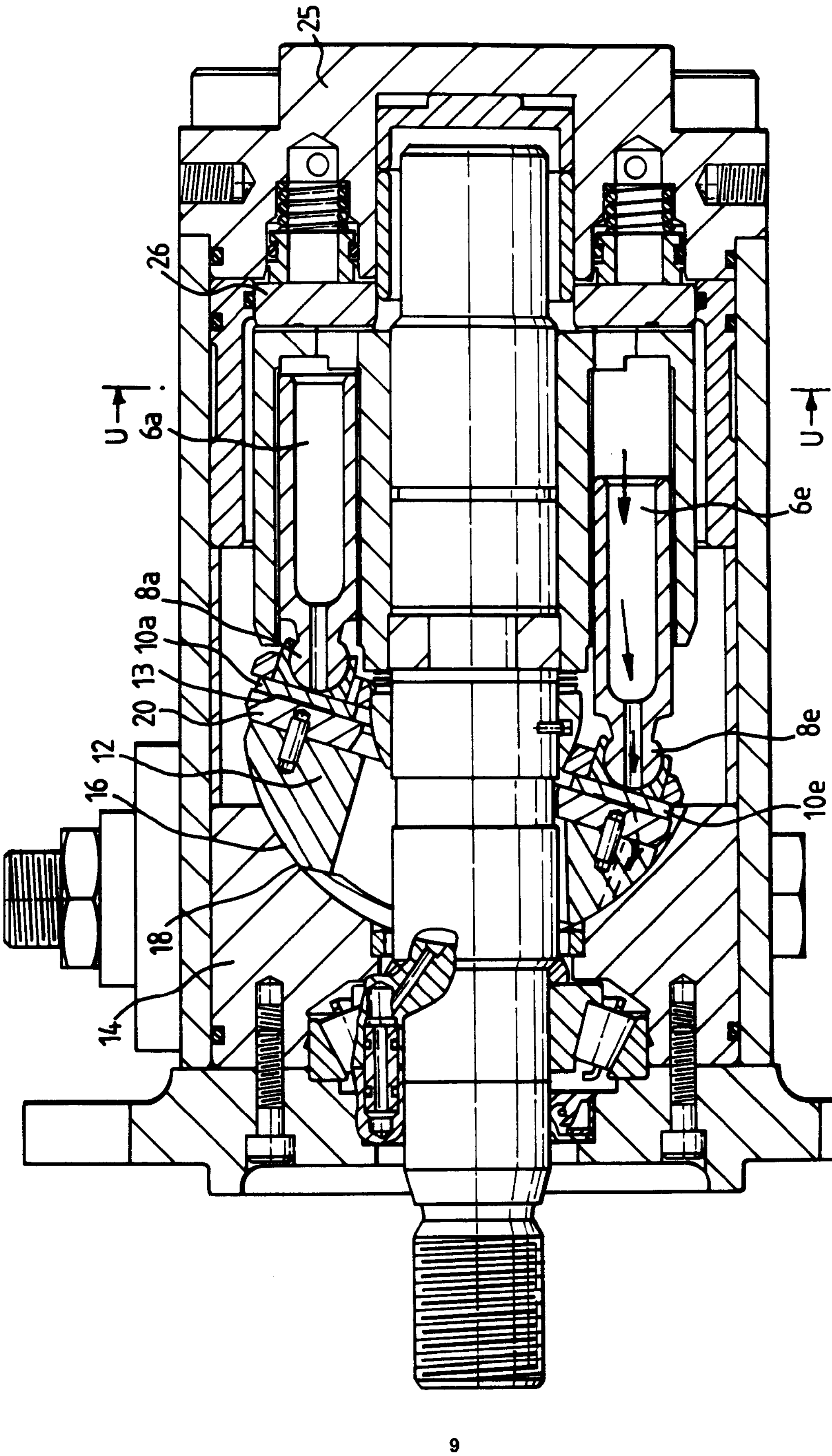

FIG.2

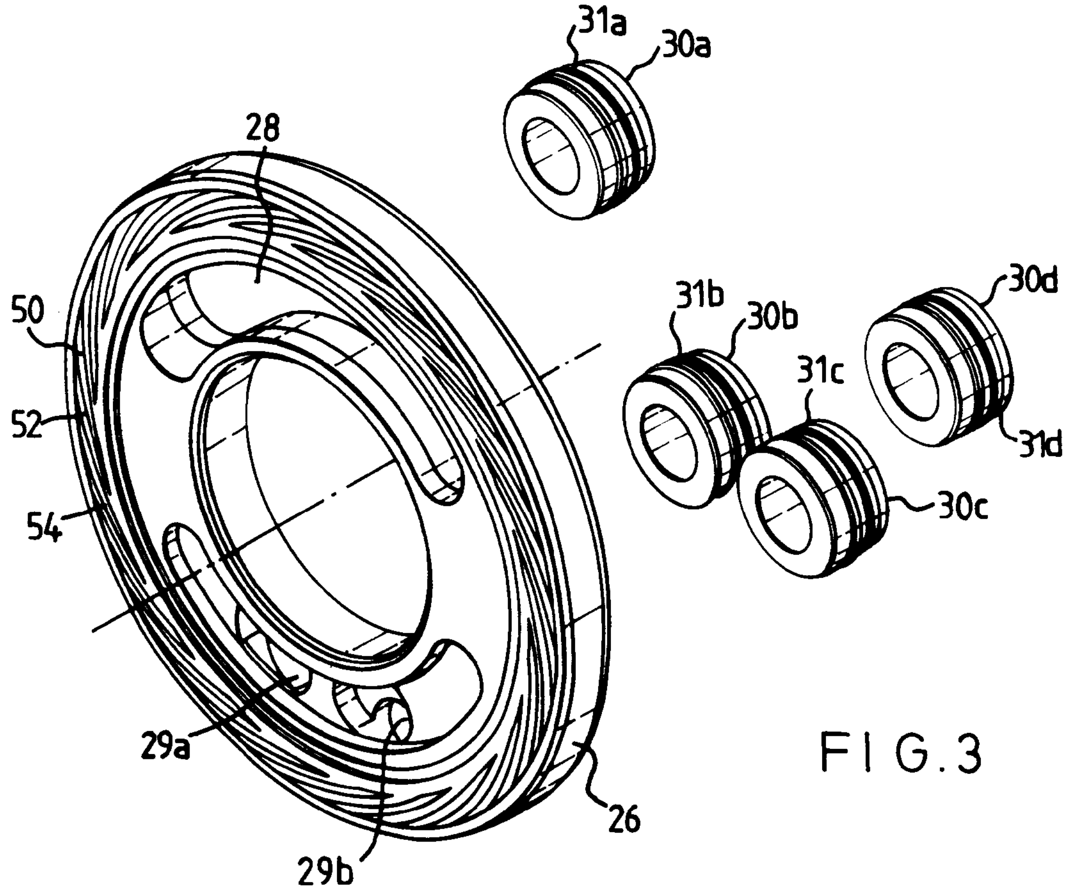
31a
30a
28
50
52
54
31b
30b
31c
30d
31d
30c
29a
29b
26

FIG.3

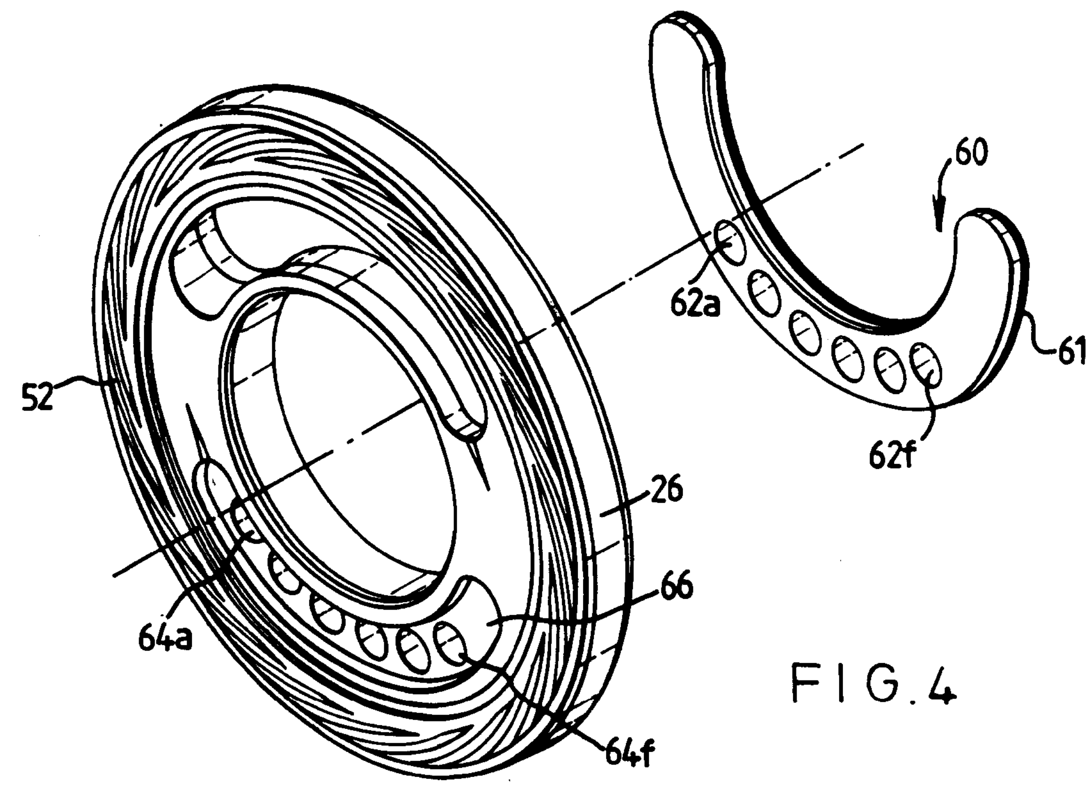
60
62a
61
52
62f
26
66
64a
64f

FIG.4

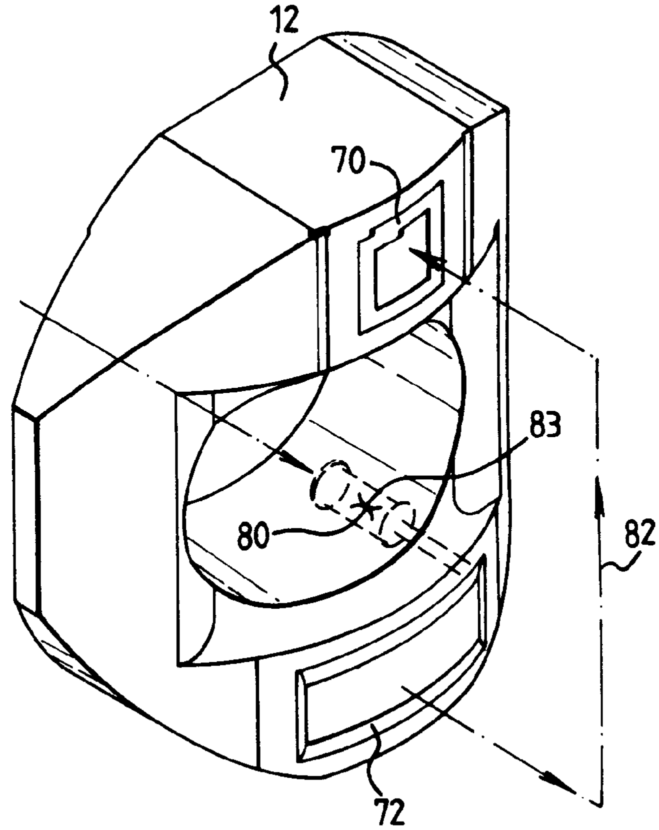

FIG.5

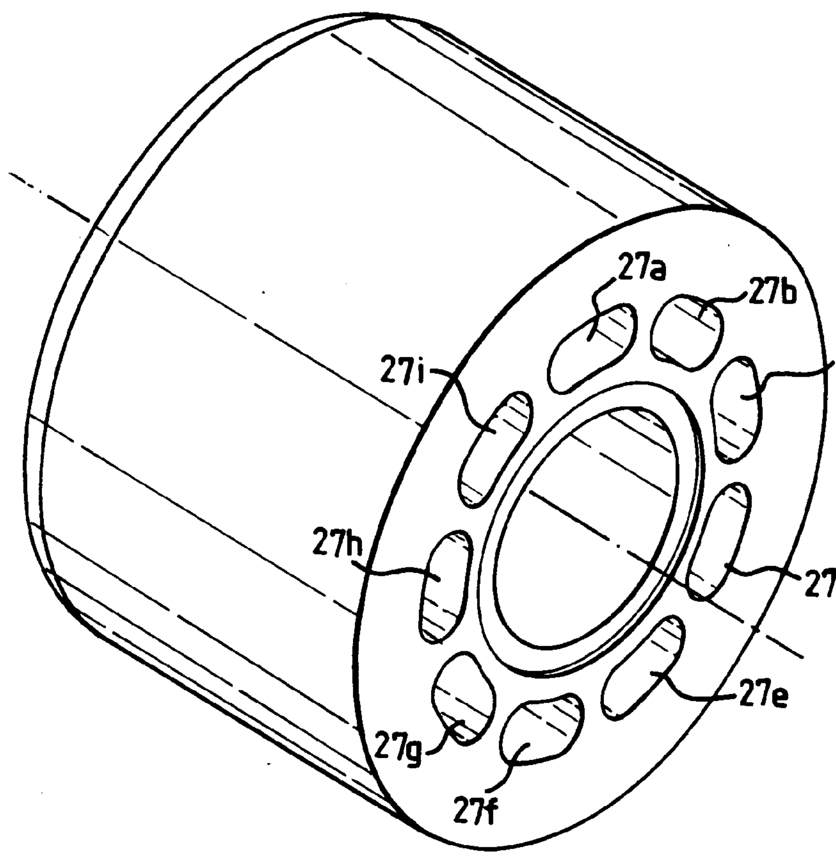

FIG.6

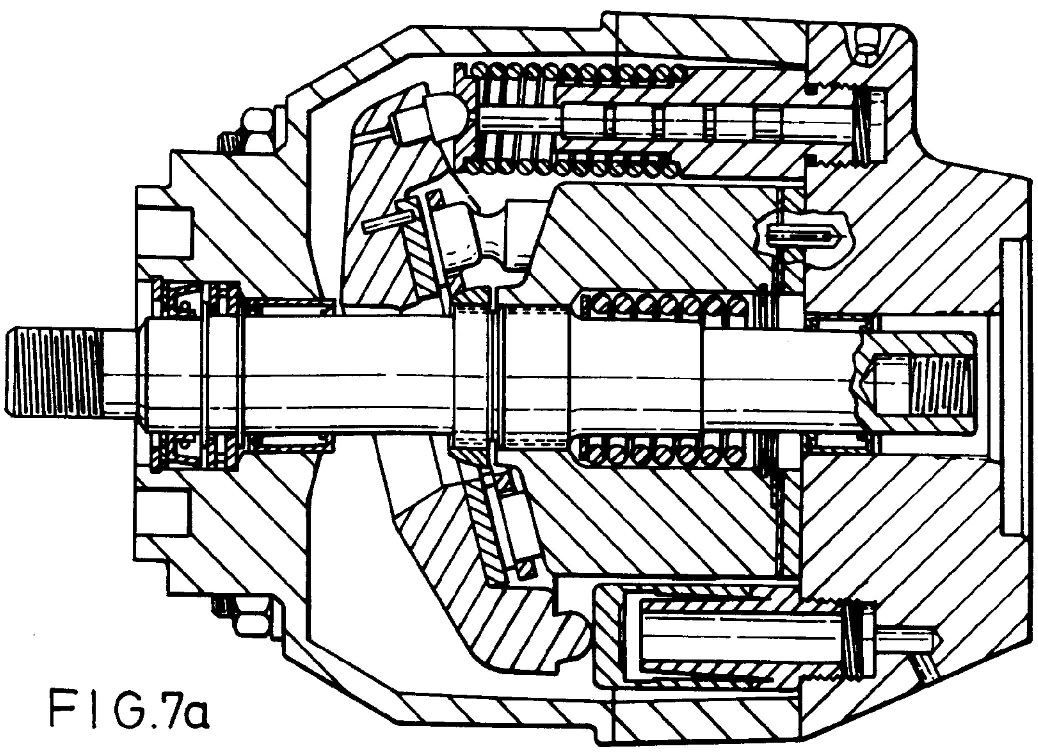

FIG.7a

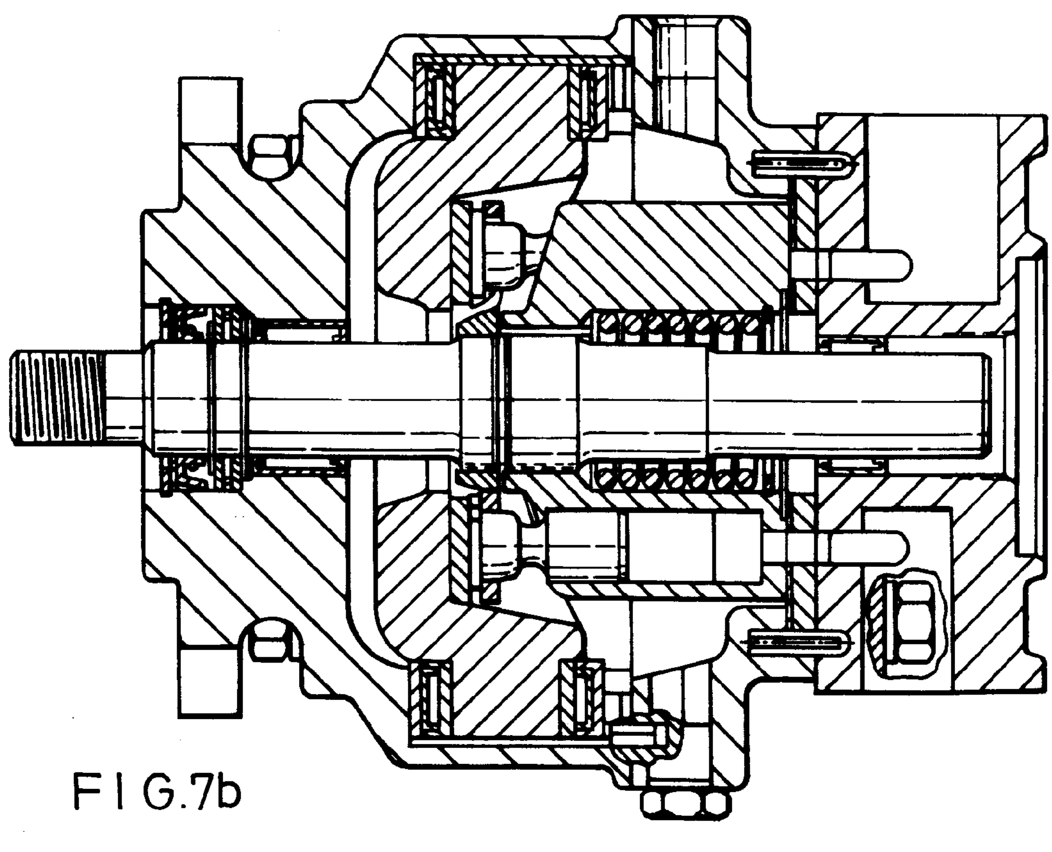

FIG.7b