Dec. 5, 1967 J. D. NORTH 3,356,037

RECIPROCATING PISTONS FOR PUMPS AND MOTORS

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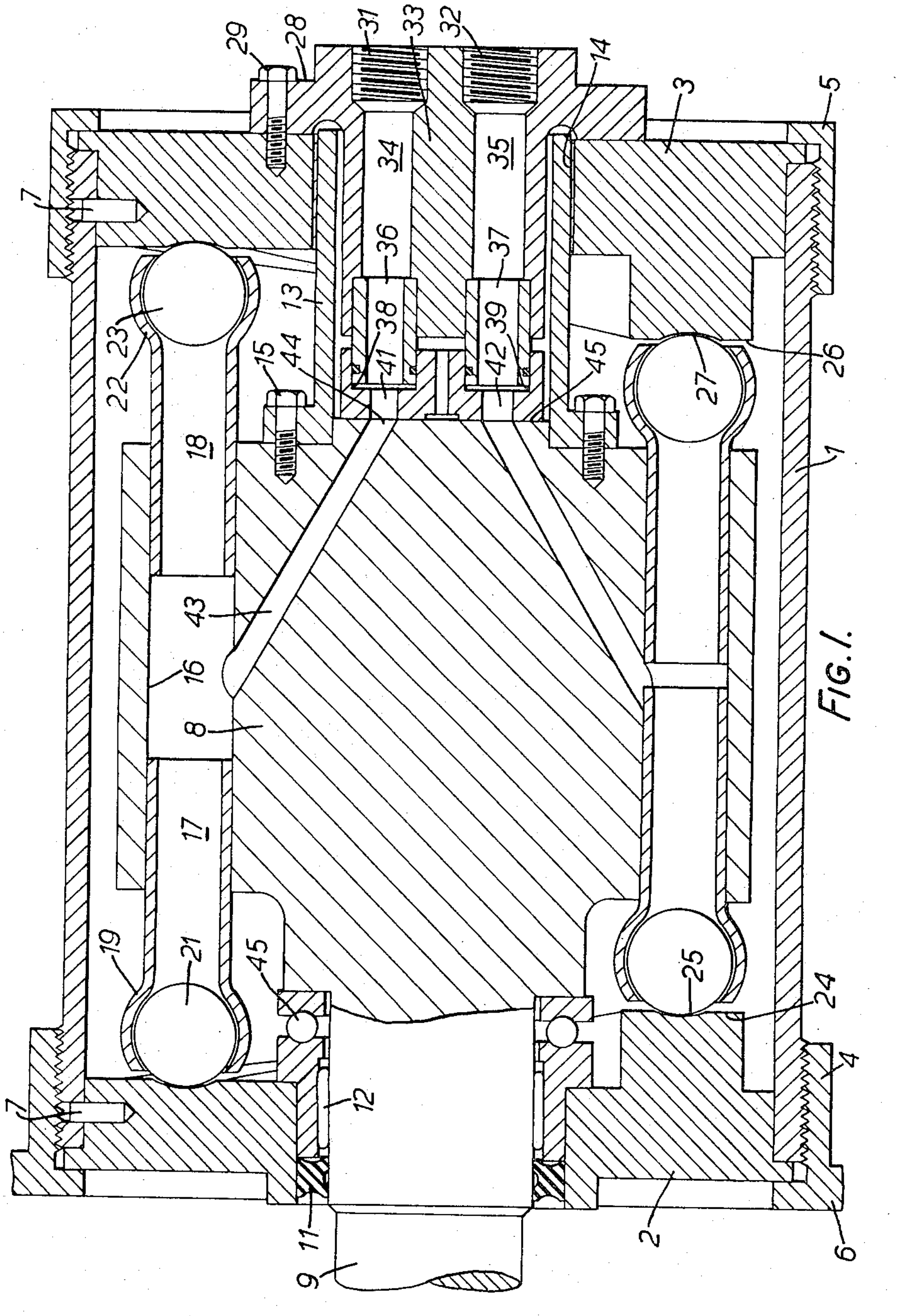

FIG. 1.

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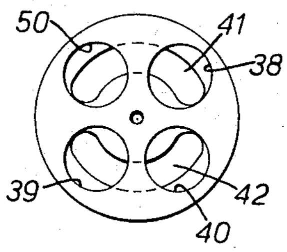

FIG. 2.

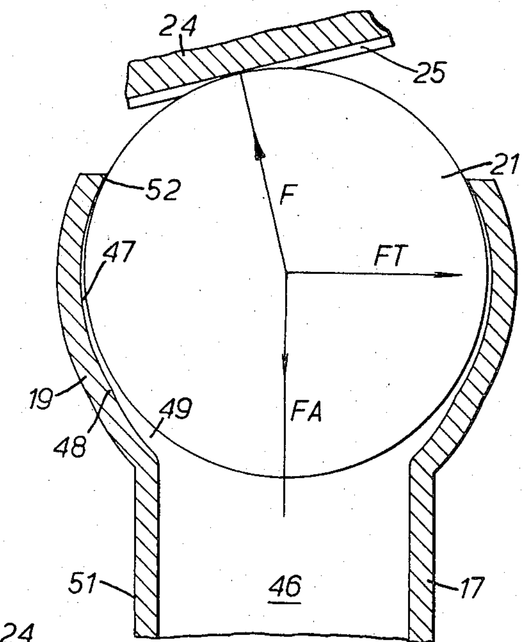

FIG. 3.

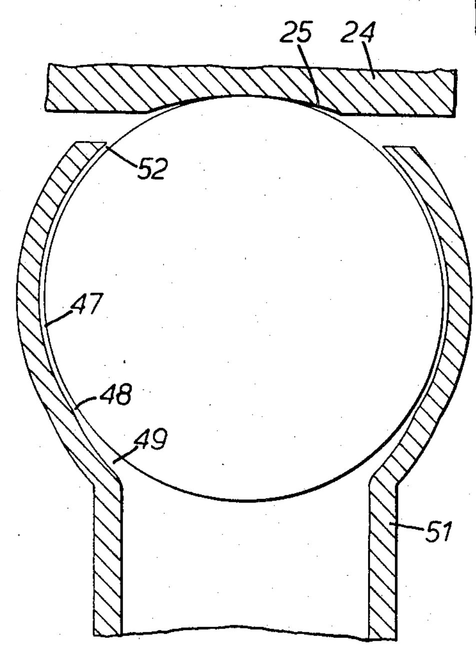

FIG. 4.

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RECIPROCATING PISTONS FOR PUMPS AND MOTORS

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4 Claims. (Cl. 103—162)

ABSTRACT OF THE DISCLOSURE

A pump or motor having one or more pistons reciprocable in cylinders by relative movement between the cylinders and a cam surface such, for example, as a swash plate unit. Each piston at its outer end, includes a cup which engages over an equatorial plane on a sphere adapted to contact the cam track, thus to transmit reciprocating forces from the cam track to the pistons. The diameter of the sphere is larger than the diameter of the displacement area of the piston. Within each cup an opening is provided, fed with hydraulic pressure from the displacement area of the piston, and having a surface area which, when projected on a plane at right angles to the axis of the piston, is larger than the displacement area of the piston. Pressure in each cylinder acting in the opening tends to push the piston away from the sphere into the cylinder. The sphere may be retained in the cup simply by physical engagement with the rim of the cup. Alternatively, the sphere may be retained by arranging the rim of the cup to have a smaller diameter than the diameter of the piston, so that the sphere may be hydraulically balanced within the cup. Again, alternatively, the opening may be fed from the piston displacement area, with liquid through one or more restrictors, to establish a leakage balance condition between the piston and the sphere.

This invention relates to hydraulic pumps and motors having pistons reciprocable by engagement with a cam track, such for example as the swash plate of a swash plate pump or motor or the track ring of a radial cylinder pump or motor.

In such pumps or motors it is usual to provide a slipper articulated to one end of each piston for engagement against the cam track. Such a slipper can comprise a part spherical member forming part of the articulation and an integral disc-like member whose surface forms the slipper surface engaging the cam track. Such slippers are expensive to manufacture in comparison with the cost of the manufacture of a metal sphere. The object of the present invention is to provide a piston and slipper structure for a pump or motor in which the slipper is formed by a metal sphere.

In accordance with the present invention a hydraulic pump or motor includes at least one piston reciprocable to displace liquid, a metal sphere larger in diameter than the displacement diameter of the piston, arranged for rotation in the end of the piston, a cam track with which the sphere is adapted to engage, and bearing means locating the piston and cam track for relative movement during which the sphere rolls on the track and transmits reciprocating driving forces between the piston and the track.

For the purpose of the present specification a piston is defined as a member having a cylindrical surface for telescoping engagement with a cylindrical surface of a cooperating member. The cylindrical surface of the piston

may be an external surface or it may be an internal surface.

Where the cylindrical surface is an external surface the piston may either be of solid or hollow construction.

Preferably the sphere is contained in a cup formed on one end of the piston which cup embraces the sphere over an equatorial plane.

The mounting of the sphere on the piston may include openings or recesses to apply liquid under pressure to the surface of the sphere from the displacement area of the piston. In the case of a hollow piston, the sphere is contained in a cup at one end of the piston and forms the closure of the piston at that end, whereby liquid under pressure acted on by the piston may act directly over a substantial area of the sphere. For preference the area of the sphere exposed to liquid in the hollow piston is such that the resultant forces tend to urge the piston and the sphere in opposite directions, the engagement of the cup over an equatorial plane of the sphere ensuring that the sphere does not leave the cup.

Preferably the cup fits the sphere with small clearance so that liquid under pressure from the hollow piston may leak slightly between the sphere and the cup to provide adequate lubrication for the sphere as it rolls.

By closing the cup over the sphere to a smaller diameter than the diameter of the piston cylindrical surface, and allowing a small clearance between the sphere and the cup, the piston may be hydraulically balanced relatively to the sphere in the direction of piston reciprocation.

This sphere may roll in a groove formed in the cam track. The component of the force exerted by the sphere on the cam track transverse both to the groove and the direction of piston reciprocation may then be substantially resisted by the engagement of the ball in the groove.

How the invention can be carried into effect will be particularly described with reference to the accompanying drawings, in which,

FIGURE 1 is a cross-section through a hydraulic motor embodying the invention,

FIGURE 2 shows the rear surface of the valve plate used in FIGURE 1,

FIGURE 3 is a cross-section through one piston cup and sphere assembly as used in FIGURE 1, and

FIGURE 4 is a cross-section through a modified piston, cup and sphere assembly for use in FIGURE 1.

Initially reference is made to the motor illustrated in FIGURES 1 and 2. A cylindrical casing **1** is provided at either end with a swash plate member, respectively **2** and **3**, which are retained in position by screw-threaded retaining members **4** and **5** fitting on to screw threads at the two ends of the casing **1** and having inwardly projecting flanges engaging the swash plate members. The retaining member **4** is provided with an externally-directed flange **6** forming the mounting to secure the motor in its operative position. Each swash plate member is located angularly in position about the central axis of the casing by means of dowel pins **7**. Centrally within the casing a rotary cylinder block **8** is located. An integral drive shaft **9** extends from one end of the block through a central hole **11** in the swash plate member **2**. Needle roller bearings **12** locate the shaft **9** for rotation in the hole **11**. From the opposite end of the block a hollow stub axle **13** extends in to a hole **14** in the swash plate member **3**. The stub axle **13** is secured to the block by bolts **15**. A plain metal bearing within the hole **14** engages the stub axle **13** for rotation. Within the cylinder block **8** a plurality of equally-spaced cylinders **16** are formed which extend parallel to the axis of block rotation from end to end through the block. Within each cylinder **16** a pair of hollow pistons **17** and **18** are slidably mounted. The pistons **17** project from one end of the cylinder block towards the swash plate member **2** and the pistons **18** project from the other end of the cylinder block towards the swash plate member **3**. Each piston **17** at its outer end is formed with the cup member **19** within which a metal sphere **21** is rotatably mounted. Each piston **18** at its outer end is formed with cup **22** within which a metal sphere **23** is free to rotate. The spheres **21** engage on a cam track **24** formed inwardly of the swash plate member **2**. This cam track is formed with a groove **25** engaged by the spheres **21**. Similarly the swash plate member **3** is inwardly formed with a cam track **26** formed with a groove **27** in which the spheres **23** engage. The cam tracks **24** and **26** are each substantially plane and are inclined at an angle of about 80° to the cylinder block rotation axis. The grooves **25** and **27** are each circular in cross-section and of slightly greater radius than the spheres **21** and **23** that roll in them. The grooves **25** and **27** when viewed in the plane of their respective cam tracks are each elliptical in shape corresponding to the projected circular path of the pistons in the planes of the cam tracks.

A hydraulic connector **28** is secured by screws **29** to cover the hole **14** in the swash member **3** and it includes a pair of hydraulic connections **31** and **32**. A support **33** extends from the connector **28** into the interior of the hollow stub axle **13**, a pair of hydraulic passages **34** and **35** extending in the support from the connections **31** and **32**. These passages **34** and **35** terminate in a pair of cylindrical sleeves **36** and **37**. Valve plate **38** is mounted on the sleeves **36** and **37** by means of a pair of spaced recesses **38** and **39** within which the sleeves **36** and **37** make sealing contact. From the recesses **38** and **39** a pair of main ports **41** and **42** extend. These ports, as more particularly shown in FIGURE 2, are of kidney shape. From the centre of each cylinder **16** a passage **43** extends through the block, terminating in a port **44** formed in the flat surface **45** of the cylinder block over which the stub axle **13** is bolted. The cylinder ports **44** co-operate alternately with the main ports **41** and **42** during block rotation. The angular position of the valve plate **38** about the rotation axis of the block is such that pistons in cylinders connected to one main port will move outwardly and pistons in cylinders connected to the other main port will move inwardly. In order to ensure adequate balance of the valve plate **38** a pair of dummy pistons are provided in recesses **40** and **50** of the valve plate to re-act against the support **33**. The main ports **41** and **42** would not normally appear in the cross-section of which FIGURE 1 is taken, but for convenience, the cross-section through the support **33** and the valve plate **38** have been changed slightly to include the main ports **41** and **42** and the sleeves **36** and **37**.

In operation of the motor described, hydraulic pressure is supplied to one of the connections **31** or **32**. By way of example it is assumed that such pressure is applied to connection **31** and a return flow connection extends from the connection **32**. The high pressure applied to the passage **34** will obtain access to the port **41**. The action of hydraulic pressure over the area of port **41** in connection with the surface **45** will be equally and oppositely opposed by the action of hydraulic pressure over the area of the recess **38** and of the recess **50**. Hydraulic balance of the valve plate against the surface **45** is thus assured. The cylinder ports **44** in connection with port **41** will supply hydraulic pressure to the pistons **17** and **18** tending to urge them out of their cylinders whereby the tangential component of the thrust re-acted on the pistons by the spheres **19** and **23** and the cam tracks **24** and **26** will cause rotation of the cylinder block. Such rotation will cause the pistons in connection with the main port **42** to move inwardly by virtue of their engagement with the cam tracks, thereby exhausting liquid at low pressure through the connection **32**. The total hydraulic thrust exerted on the cylinder block by the valve plate **38** is re-

acted through the ball bearing **45** onto the swash plate member **2**.

Reference is now made to FIGURE 3 for a more detailed explanation of the function of each piston and its associated sphere. FIGURE 3 represents a piston **17** of which the cup **19** contains a sphere **21** but it could equally represent piston **18**. The piston **17** is a hollow sleeve, the interior **46** of which is filled with liquid at pressure, and the associated cylinder port **44** connects to the main port **41**. The cup **19** and piston **17** are integrally formed so that the cup encloses the ball **21** with a very small clearance **47** between the ball and the interior of the cup. The ball **21** is bodily movable within the cup within the limits permitted by the small clearance **47**. The interior of the cup adjacent to the piston **17** is formed with a small ridge **48** against which the ball **21** will engage if it moves towards the piston **17**. From the ridge **48** to the interior **46** of the piston there is an increasing clearance **49** from the sphere **21**. The ridge **48** is a circular ridge whose diameter is slightly greater than the outer cylindrical surface **51** of the piston **17**, this surface being that which fits into the cylinder **16**. If the sphere **21** moves within the cup onto the ridge **48**, the effective area of the sphere over which hydraulic pressure in the space **46** will act on the sphere, will produce between the sphere and the piston a force greater than the total force producible by the action of liquid pressure over the cross-sectional area of the cylindrical surface **51**. In fact the ridge **48** ensures that the sphere **21** will be urged outwardly of the cup **19** to engage the outer rim **52**.

In operation, whenever pressure exists in the associated cylinder **16**, the pressure will effectively act over a substantial area of the sphere **21** to hold it against its associated groove **25** and, at the same time, pressure will re-act on the cup and piston in the clearances **47** and **49** to urge the piston inwardly into the cylinder with a smaller force than that exerted on the sphere **21**. The result is that the cup and piston will take up a position relatively to the sphere, as shown in FIGURE 3, whenever there is any substantial pressure in the associated cylinder. The reaction between the cam track **24** and the sphere **21** is a force F indicated in FIGURE 3 in a direction perpendicular to the cam track **24** through the centre of the sphere **21**. This force F is resolvable into two components, FA and FT. The component FA extends axially along the piston **17** and reacts directly against the effective force of the liquid on the piston and sphere. The force FT is the tangential component reacting between the sphere **21** and the cup **19** to produce rotary driving torque on the cylinder block **8**. Another force component of the force F acts in a direction radially of the rotation axis of the cylinder block. By virtue of the groove **25** a very slight movement of the sphere within its permisssible bodily movement within the cup **19** will cause the sphere to engage a part of the groove such that the radial force component is transmitted directly to the groove and does not react on the cup **19**.

A modified version of the piston, cup and sphere arrangement is shown in FIGURE 4. The modification comprises moving the rim **52** of the cup to a position radially inwards of the projected position the cylindrical surface **51** of the piston. When the sphere is at its outermost position in contact with the rim **52**, hydraulic pressure acting on the sphere within the clearances **47** and **49** will react to cause movement of the cup so that the ball will move slightly towards the ridge **48** until a balance is achieved whereby the integrated hydraulic pressures acting axially of the piston on the sphere over the area enclosed by the cup will exactly balance the hydraulic thrust acting axially on the piston sleeve **17**. Slight axial movement of the sphere within the cup will alter the relative pressure drops at the ridge **48** and the rim **52** always to restore hydraulic balance of the sphere axially within the cup.

In the embodiments of piston, cup and sphere assembly shown in FIGURES 3 and 4, the sphere when in use will roll over the cam track such rolling being facilitated by the hydraulic film of liquid formed in the clearance between the sphere and the cup. The resistance to motion of the cylinder block relatively to the cam track is therefore very small since the rolling resistance of the ball on the track is correspondingly small and since the rolling movement within the cup will also be small due to the presence of the liquid film.

The cost of manufacturing a piston, cup and ball assembly, as shown in FIGURES 3 and 4, may be quite small since the spheres may be standard ball bearings made cheaply in accordance with standard manufacturing techniques and the cup may be simply engaged around the sphere by a conventional rolling or spinning operation.

In the described embodiment, which is particularly intended for use as a motor, no springs are provided in the cylinders to assist the pistons in their outward movement. Springs may be omitted because the illustrated embodiment is for use as a motor and the applied hydraulic pressure will push the pistons outwardly. The return motion of the pistons into their cylinders cannot result in the spheres coming disengaged from the cam tracks. In the case of a pump working on the swash plate principle wherein the entry pressure liquid into the pump is very low, it will be necessary to provide springs in the cylinders to urge the pistons outwardly so that the spheres will positively engage the cam track, such outward movement under spring action then inducing liquid to enter the cylinders.

Whilst the described embodiment of the invention is for a unit of the swash plate type the invention may also be used with units of the inclined cylinder and radial rotary cylinder block kind. In such cases centrifugal force acting on the piston, cup and sphere assemblies will ensure that they remain in contact with their respective cam tracks under all circumstances without the assistance of springs. The invention in the described embodiment shows a rotary cylinder block form of swash plate motor. It will be appreciated that the invention is equally usable with swash plate axial and inclined cylinder units and radial cylinder units where the cylinder block is stationary and the cam track formed by a swash plate or the like rotates relatively to the cylinder block to cause piston reciprocation. Such units when used for pumping from a low pressure source will need the assistance of springs within the cylinders to hold the spheres against the cam tracks.

I claim as my invention:

1. A hydraulic pump or motor including at least one piston reciprocable to displace liquid, a cup formed on one end of the piston, a sphere larger in diameter than the displacement diameter of the piston, engaged within the cup over an equatorial plane for rotation in the cup, a cam track with which the sphere is adapted to engage, said piston being hollow and there being an opening within the cup connected to receive liquid at pressure from the displacement area of the piston, the total effective area of said opening, when projected into a plane at right angles to the axis of the piston, being greater than the displacement area of the piston, and bearing means locating the piston and the cam track for relative movement during which the sphere rolls on the cam track and transmits reciprocating driving forces to the piston, said cup engaging the sphere with very small clearance and the rim of the cup having a slightly smaller diameter than the displacement area of the piston whereby the piston is hydraulically balanced relative to the sphere in the direction of piston reciprocation.

2. A hydraulic pump or motor as claimed in claim **1** including a circular ridge formed in the cup, engageable by the sphere on movement within the cup, to limit movement of the sphere towards the piston, the diameter of the ridge defining the edge of the opening.

3. A pump or motor as claimed in claim **1**, including a groove formed in the cam track within which the sphere is adapted to roll.

4. A hydraulic pump or motor comprising a rotary cylinder block, cylinders in the block disposed parallel to the rotational axis, a fixed swash-plate disposed adjacent to one end of the cylinder block, and a piston and sphere assembly as claimed in claim **1** provided in each cylinder such that the sphere engages the swash-plate.

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