Dec. 9, 1969 E. A. DI BARTOLO ET AL 3,482,525

ROTARY PUMP OR MOTOR

Filed March 4, 1968 2 Sheets-Sheet 1

Fig. 1.

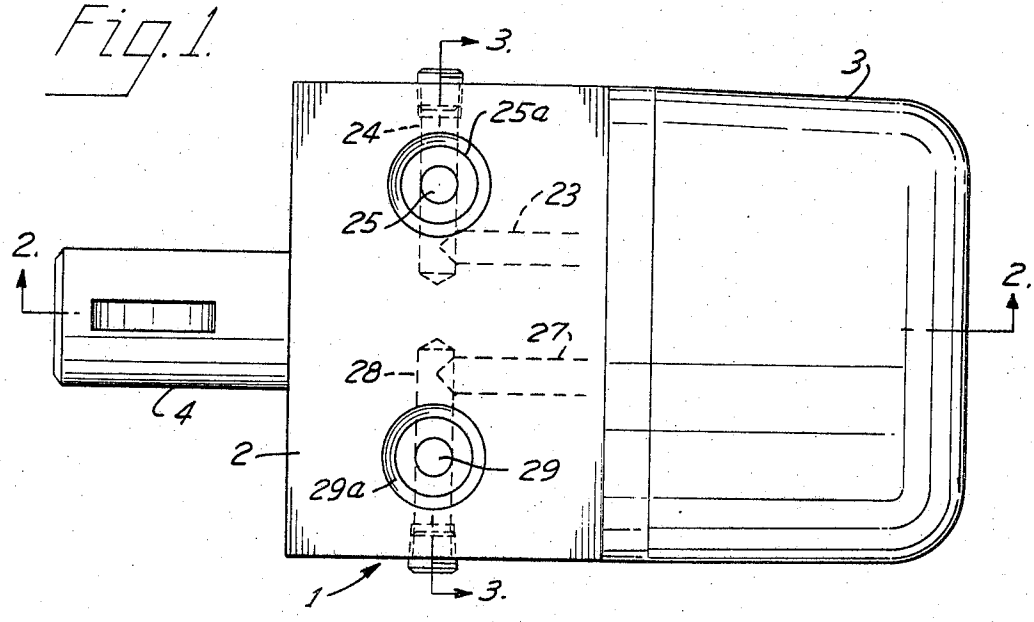
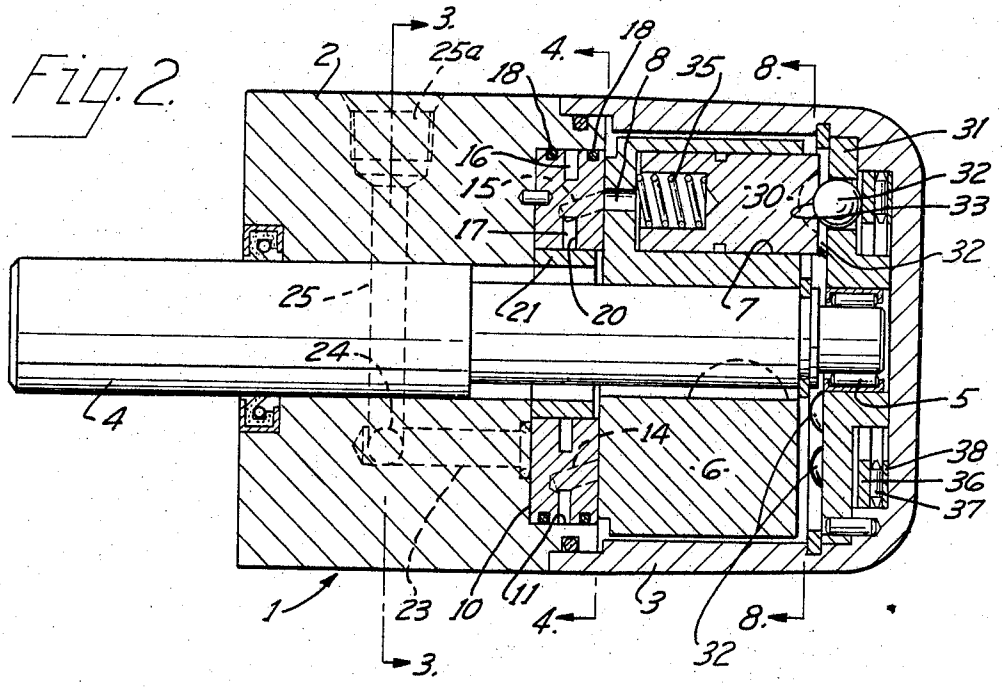


Fig. 2.



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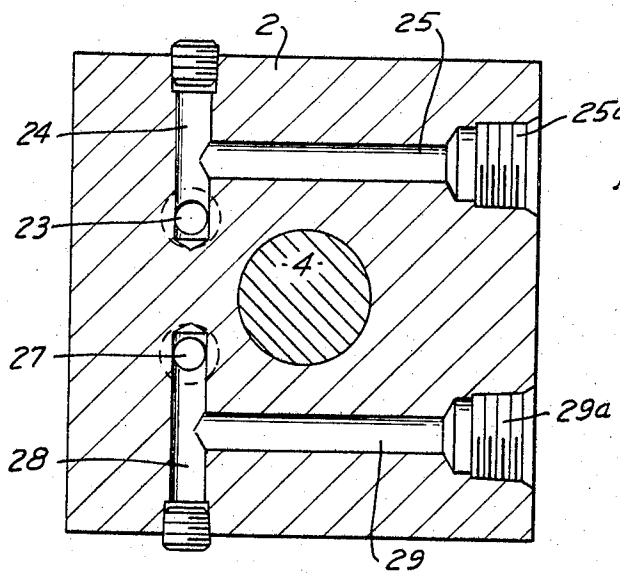

Fig. 3.

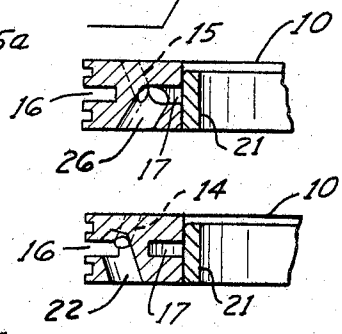

Fig. 6.

Fig. 7.

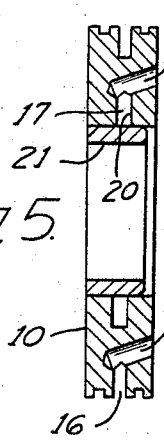

Fig. 5.

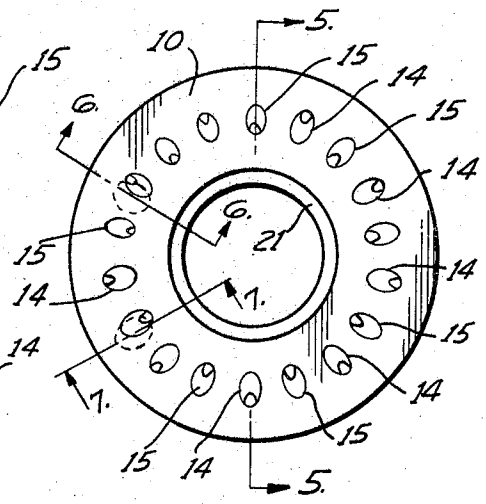

Fig. 4.

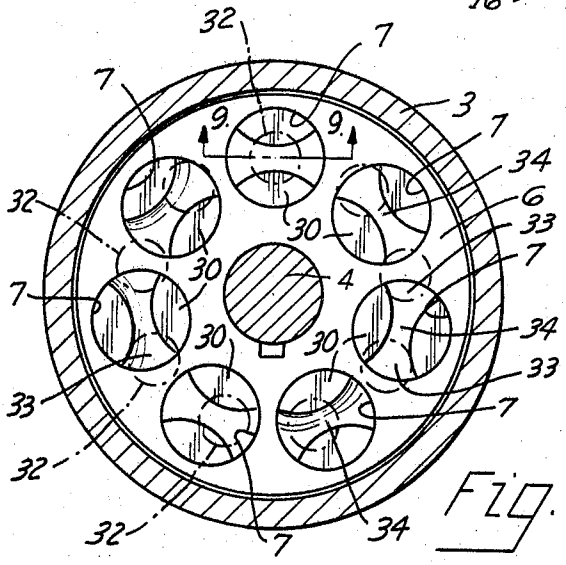

Fig. 8.

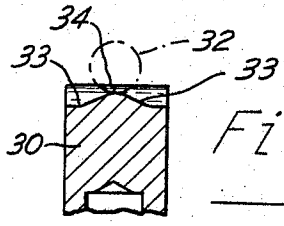

Fig. 9.

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ROTARY PUMP OR MOTOR

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Int. Cl. F04b 1/22; F01b 13/04; F16h 25/12
U.S. Cl. 103—162 8 Claims

ABSTRACT OF THE DISCLOSURE

The preferred form of pump or motor herein disclosed comprises a rotor having a power shaft and a plurality of cylinders arranged in laterally spaced relation to each other in a row extending circumferentially of the rotor axis. Each cylinder accommodates a piston and has a port cooperable successively with inlet and exhaust ports in a port plate.

The pistons are driven on their power strokes by a reactance having a plurality of lobes arranged in fixed position in a row extending circumferentially of the rotor axis.

The pump or motor is characterized by the following:

Each piston has, on its outer end, a cam surface which is engaged successively by the lobes during rotation of the rotor.

Each lobe is a roller, preferably a ball rotatable in all directions about its own center, which center is fixed in position circumferentially of the rotor axis. The size, number, and spacing of the cylinders and balls are such that each piston is always in engagement with at least one ball.

The balls bear against a common rotatable reactance plate coaxial with the rotor axis and which, in turn, is antifrictionally supported by a circumferential row of antifriction cageless needle rollers which roll on a rigid stationary race or thrust plate.

This invention relates to a bi-directional rotary pump, motor or hydraulic transmission which operates with high efficiency not only at normal, but also at very slow shaft speeds.

The structure, whether used as a pump or motor, or in a pump-motor transmission, is of general utility in the field of hydraulic pumps and motors.

For purposes of illustration, the present invention is described herein as applied to a rotary pump, it being understood that a like structure also can be connected by conventional hydraulic circuitry to function as a motor and two such structures can be connected to provide a hydraulic transmission.

The pump has a plurality of piston and cylinder assemblages with cooperable reactance lobes and fluid ports so arranged that each piston makes a large number of complete strokers per revolution. As one example, the pump may employ nine ports and aligned lobes, and seven pistons, whereby each piston may make nine pressure strokes and nine suction strokes for each revolution of the rotor, a total of sixty-three complete cycles for each revolution of the rotor.

The type of arrangement of the cooperating elements of the pump or motor are such that the frictional resistances developed are very low.

A specific example of the very slow speed application of the structure is as a pump driven by the pilot or steering wheel of a boat and, in turn, as a steering motor of like construction connected to the pump and driven by the pressure fluid delivered by the pump.

Other specific applications, objects, and advantages of

the invention will become apparent from the following description wherein:

FIG. 1 is a top plan view of a pump or motor embodying the principles of the present invention;

FIG. 2 is a longitudinal vertical sectional view taken on the line 2—2 in FIG. 1;

FIG. 3 is a vertical cross-sectional view taken on the line 3—3 in FIGS. 1 and 2;

FIG. 4 is a view of the port plate used in the present invention, as viewed from the line 4—4 in FIG. 2;

FIG. 5 is a vertical longitudinal sectional view of the plate illustrated in FIG. 4 and is taken on the line 5—5 in FIG. 4;

FIG. 6 is a fragmentary radial sectional view of the plate taken on the line 6—6 in FIG. 4;

FIG. 7 is a fragmentary radial sectional view of the plate taken on the line 7—7 of FIG. 4;

FIG. 8 is a fragmentary cross-sectional view of the pump, taken on line 8—8 of FIG. 2, showing the outer ends of the pistons and their relation to the lobes of the cam of the reactance; and

FIG. 9 is a fragmentary longitudinal sectional view of one of the pistons and is taken on the line 9—9 in FIG. 8.

Referring to the drawings, the pump or motor comprises a body 1 including a block 2 and a casing 3 secured to one end of the block. Mounted within the body 1 is a power transmission means in the form of a rotatable shaft 4 which extends out of one end of the body 1 and at its innermost end is mounted in suitable antifriction rollers 5 in the casing 3. Supported on the shaft 4 in coaxial relation thereto and for rotation therewith is a rotor 6 having a plurality of circumferentially spaced cylinders 7. In the form illustrated, the cylinders 7 are arranged with their axes parallel to the axis of rotation of the rotor. The cylinders are spaced radially outwardly from the rotor axis and arranged in laterally spaced relation to each other in a row extending circumferentially of the rotor axis. Thus the rotor 6 and cylinders 7, with the ducts 8, comprise a body assemblage. Each cylinder 7 has a port 8 at its inner end. An annular plate 10 is disposed in a bore 11 in the inner end of the block 2 so as to be disposed in sliding engagement with the port or inner face of the rotor 6. The port plate 10 has inlet ports 14 and outlet ports 15 arranged in alternation in a row extending circumferentially of the axis of rotation. This row of inlet and outlet ports is in alignment, axially of the rotor, with the row of ports 8 so that each port 8, upon rotation of the rotor, communicates successively alternately first with a port 14 and then with a port 15. All of the inlet ports are connected to an outer annular passage 16 in the port plate 10 and all of the ports 15 are connected to an inner annular passage 17 in the port plate 10. The passages 16 may be provided by forming an externally open peripheral groove in the plate 10 and installing the plate 10 in the bore 11 of the block 2, with O-rings 18 disposed in grooves in the plate 10 at opposite sides, axially of the plate 10, of the peripheral groove. Thus the peripheral groove forms with the wall of the block 2 a sealed annular passage 16.

Correspondingly, the passage 17 is provided by an inwardly open annular groove 20, sealed at its open side by means of a sleeve 21.

All of the ports 14 are connected to the outer passage 16 and all of the ports 15 are connected to the inner passage 17. The passage 16 is connected by a duct 22, shown in FIG. 7, in the port plate 10 to a longitudinal duct 23, shown in FIG. 2, in the block 2. The duct 23 is connected with a transverse duct 24 which is connected to another transverse duct 25. The duct 25, at its outer end, has a large counterbore 25a threaded for connection to a con-

duit of an external hydraulic circuit, such as a reservoir or return line from a hydraulic device to be driven.

Correspondingly, as illustrated in FIG. 6, the inner passage **17** is connected by a duct **26** in the port plate to a longitudinal duct **27** in the block **2**. The duct **27** is connected to a transverse duct **28**. The duct **28** is connected to a transverse duct **29** which, at its outer end, has a large counterbore **29***a* internally threaded for connection to the opposite of the external hydraulic circuit. Pistons **30** are reciprocable in the cylinders **7**, respectively.

Upon rotation of the rotor **6** with proper reciprocation of the pistons **30**, pressure fluid is drawn into each cylinder successively through its port **14** and pressure fluid delivered from each cylinder through its port **15**. If, of course, the device operates as a motor, then the operating pressure fluid is delivered to each cylinder through its port **15** and the fluid is exhausted through its port **14**, successively, during each revolution.

In order to operate the pistons **30** in proper sequence in relation to the alignment and disalignment of the cylinder ports **8** with the ports **14** and **15**, a stationary multilobed reactance assemblage is provided in the body, preferably at the end of the casing **3** opposite from the block **2**. The reactance assemblage is one which combines characteristics of multi-lobed stationary reactance and a rotary reactance. Its lobes are fixed in position circumferentially of the axis of rotation, yet are in rolling pressure engagement with cam surfaces on the outer ends of the pistons. For this distinctive type of driving relation between the pistons and reactance, the reactance is in the form of a stationary plate **31** having a plurality of passages therethrough in which are disposed rollers which, in the form illustrated, are balls **32**. These balls **32** are disposed in a row about the axis of rotation of the rotor in axial alignment with the ports **15**, respectively.

The balls **32** are secured by the plate **31** with their centers in fixed circumferential position relative to the axis of rotation, and they protrude at the face of the plate **31** toward the pistons **30** a preselected distance beyond that face of the plate. Each piston **32** is provided with a cam surface **33** on the end facing the balls **32**. These cam surfaces may be milled so as to extend in only one radial direction across the ends of the pistons, as illustrated in FIG. 9, or turned, so as to be the same in section in all longitudinal radial planes through the piston axis, and are arranged so that in the direction of rotation of the rotor, each cam surface rises in a direction toward the balls to a crest **34** and then recedes or declines, at the opposite side of the crest, away from the balls to the level of the surface at the point of initial engagement of the ball therewith. This shape is such that the piston **30** is driven on its pressure stroke as the ball **32** rides along the cam toward the crest **34**. As the ball rides along the cam beyond the crest, the piston is freed from movement on its return stroke. When used as a pump, this return stroke is effected by suitable return springs **35** disposed in bores in the inner ends of the pistons and bearing against the inner end walls of the cylinder.

The milled cam surface is preferred as it is in the form of a trough of which the side walls act as guide walls and, by engaging the balls, constrain the pistons from rotating relative to their cylinders.

The diameters of the pistons **30**, positions of the balls **32** and ports **14** and **15**, and the like are so arranged that the cam surface **33** of each piston is always in contact with at least one of the balls **32**. As the piston passes, in the direction of rotation, out of contact with any one ball **32**, it concurrently passes into contact with the next succeeding ball **32** in the row, there being a slight overlap to assure that the piston is always in contact with at least one of the balls.

With this arrangement, a large number of complete cycles, each comprising a pressure stroke and a suction stroke, can be obtained for each piston for each rotation of its rotor. For instance, in the form illustrated, nine

outlet ports **15** and nine inlet ports **14** are provided. The balls **32** are so arranged that each piston is driven to its innermost position while it is aligned with an outlet port **15** and is returned in the opposite direction when aligned with an inlet port **14**. The diameters of the ports **8** of the pistons and of the ports **14** and **15** of the plate **10** are such that there is a slight dwell period between the passage of the piston port from one of the plate ports to the next succeeding plate port during which period the piston port **8** is disconnected from both adjacent plate ports.

The cam surfaces **33** are correspondingly formed for accommodation to this dwell so that any possibility of connection of a cylinder port with an inlet port and outlet port concurrently is eliminated, as also is the possibility of locking the piston hydraulically and developing excessive fluid pressures on the pressure strokes. This facilitates manufacture.

To reduce frictional and inertial losses that would be generated were each ball rotatable entirely independently of the others, the rotary forces of each ball are translated and transmitted to the other balls. To obtain this result and assure that the balls **32** are at all times rotating, a rotatable thrust or reactance plate **36** is arranged at the face of the plate **31** opposite from the pistons **30** and is in rolling engagement with the balls **32** at a location opposite from the pistons. The thrust plate **36** acts as a ball bearing race and rotary reactance member and is mounted in fixed axial position on a circumferentially extending row of radially extending thrust bearings, such as needle rollers **37**, which, in turn, roll on an outer thrust race or stationary reactance plate **38**. The plate **38** is firmly seated in fixed position in the end of the casing **3** and acts as a stationary reactance member.

Thus, assuming the structure is operated as a pump, the shaft **4** is rotatively driven and, in turn, rotates the rotor **6**, causing the cams **32** of the pistons **30** to cooperate with the roller lobes or ball **32** of the reactance to provide for successive piston cycles of one pressure and one return stroke each. During each cycle, hydraulic fluid is drawn into each cylinder through the ducts **25, 24, 23**, and **22**, passage **16**, and ports **14**, and is delivered under pressure through the ports **15**, passage **17**, and ducts **26, 27, 28** and **29**.

On the other hand, if the pump is to be used as a motor, pressure fluid from an extraneous source is supplied through the ports **15** and exhausted to a sump or reservoir or a return line through ports **14**.

While the pump has been described as employing pistons and cylinders parallel to the axis of rotation, the invention can be incorporated in a pump or motor in which the pistons extend radially of the axis of rotation.

From the foregoing description, it is apparent that the pump or motor is bi-directional, and is inherently balanced hydraulically.

For a given physical size, it has a maximum displacement for each revolution of the shaft because each piston has a large number of strokes for each shaft revolution.

As a result of providing the cam surfaces on the pistons, the optimum flow characteristics for selected applications can readily be provided without change in the basic structure by changing the generated cam surfaces on the piston ends. This can be done by simple milling or turning operations, depending upon whether the cam surface is to be discontinuous or continuous, circumferentially of the piston.

Having thus described our invention, we claim:

1. In a rotary pump or motor,

a body assemblage;

a multi-lobe reactance assemblage;

means supporting the assemblage for rotation relative to each other about a predetermined fixed axis;

said body assemblage including a body having a plurality of cylinders spaced outwardly radially from said axis and arranged in laterally spaced relation to each other in a row extending circumferentially of said

axis, port means for cylinders, respectively, and pistons reciprocable in the cylinders, respectively;

valve means cooperative with the port means to connect the cylinders successively to a fluid inlet and a fluid outlet upon said relative rotation of said assemblages;

said reactance assemblage being fixed in position axially of the body and including a plurality of lobes cooperative with the pistons during said relative rotation of the assemblages;

characterized in that:

each piston has, on its end adjacent to the reactance assemblage, a cam surface which is in fixed non-rotatable relation thereto, which in a direction circumferentially of the assemblages extends generally diametrically of the piston, and which, in a direction from one limit to the other in said circumferential direction rises toward the reactance assemblage to a crest and then recedes from the crest;

the lobes of the reactance assemblage are roller elements, respectively, spaced outwardly from said axis and circumferentially from each other in a row aligned with the row of cylinders, and arranged for rolling engagement successively with, and for disengagement successively from, said cam surfaces during relative rotation of the assemblages;

constraining means are provided and constrain said roller elements in fixed position relative to each other circumferentially and radially of said axis and axially of the body;

said reactance assemblage and restraining means include additionally a rotary reactance member;

means support the reactance member for free rotation about said axis relative to, and independently of, the constraining means and relative rotation of said assemblages by the rolling frictional forces imposed thereon by the roller elements;

said reactance member has one face facing toward the body assemblage and in continuous force transmitting rolling engagement with all of the roller elements; all radial cross sections of said face are equidistant from a plane normal to said axis; and

said face is shaped to constrain the roller elements from movement endwise of said axis away from the body.

2. The structure according to claim 1 characterized in that antifriction means are provided and antifrictionally support the rotary reactance member for said rotation relative to the constraining means and body.

3. The structure according to claim 2 wherein said antifriction means comprise means having a circumferential track member coaxial with the rotary reactance member and in fixed position axially relative thereto and to the body; and

antifriction rollers are disposed in load transmitting rolling engagement with said circumferential track member and said rotary reactance member.

4. The structure according to claim 1 wherein said roller elements are ball bearings and the constraining means and rotary reactance member support each ball bearing for rotation about its center.

5. The structure according to claim 1 wherein spring return means are provided for the pistons, respectively, and bias the pistons endwise of the cylinders, respectively, toward the reactance assemblage.

6. The structure according to claim 1 wherein the pistons are arranged with their axes parallel to said rotational axis and the roller elements are balls arranged in a row coaxial with the cylinder assemblage at one end of said assemblage.

7. The structure according to claim 1 wherein the number of pistons in said row of pistons is less than the number of roller elements in said row of roller elements.

8. In a rotary pump or motor,

a body assemblage;

a multi-lobe reactance assemblage;

means supporting the assemblages for rotation relative to each other about a predetermined fixed axis;

said body assemblage including a body having a plurality cylinders spaced outwardly radially from said axis and arranged in laterally spaced relation to each other in a row extending circumferentially of said axis, port means for cylinders, respectively, and pistons reciprocable in the cylinders, respectively;

valve means cooperative with the port means to connect the cylinders successively to a fluid inlet and a fluid outlet upon said relative rotation of said assemblages;

said reactance assemblage being fixed in position axially of the body and including a plurality of lobes cooperative with the pistons during said relative rotation of the assemblages;

characterized in that:

each piston has, on its end adjacent to the reactance assemblage, a cam surface which is in fixed-nonrotatble relation thereto, which in a direction circumferentially of the assemblages extends generally diametrically of the piston and which, in a direction from one limit to the other in said circumferential direction rises toward the reactance assemblage to a crest and then recedes from the crest;

the lobes of the reactance assemblage are roller elements, respectively, spaced outwardly from said axis and circumferentially from each other in a row aligned with the row of cylinders, and arranged for rolling engagement successively with, and for disengagement successively from, said cam surfaces during relative rotation of the assemblages;

constraining means are provided and constrain said roller elements in fixed position relative to each other circumferentially and radially of said axis and axially of the body;

the circumferential spacing of the roller elements and pistons, the circumferential extents of the cam surfaces, respectively, and the diameter of the roller elements are so related to each other dimensionally that, upon relative rotation of the assemblages, as the trailing portion of each cam surface is disengaging any one of the roller elements, the leading portion of the same cam surface is engaging the next succeeding roller element in the row; and each piston has guide wall portions alongside its cam surface arranged to engage the roller elements and thereby constrain the associated piston from rotation relative to the cylinder about the piston axis.

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WILLIAM L. FREEH, Primary Examiner

U.S. Cl. X.R.

91—198; 74—22

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,482,525 Dated December 9, 1969

Inventor(s) Ernest A. DiBartolo et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 40, "ducts 8" should read -- ports 8 --.
Column 6, line 62, "2,819,687" should read -- 2,819,678 --.

Signed and sealed this 7th day of March 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

USCOMM-DC 60376-P69