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[54] **FLUID MOTOR**
15 Claims, 7 Drawing Figs.

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 91/192, 91/477, 92/68, 92/146

[51] Int. Cl..... **F011 21/02**

[50] Field of Search..... 91/184,
 192; 107/(Inquired); 103/160; 92/76, 68, 61,
 (Cursory), 146; 123/43C, (Cursory)

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ABSTRACT: A stationary body has two sets of cylinders, each cylinder in a first set being paired to a cylinder in the second set. Each cylinder is open at one end and has an actuation chamber at the other end and, in between the ends, a valving recess in between an inlet recess and an outlet recess. An inlet passage leads to each inlet recess and an outlet passage leads to each outlet recess. Each of the paired cylinders has its valving recess connected to the actuation chamber of the other cylinder of the pair, so that each piston serves as a valve for its paired piston. A rotatable housing has two internal circumferential cam rings. A link is associated with each piston and pivotally mounted to the body, each link having (1) a piston-engaging roller mounted thereon in contact with the outer end of its associated piston and (2) a cam roller mounted thereon and in engagement with one of the cam rings.

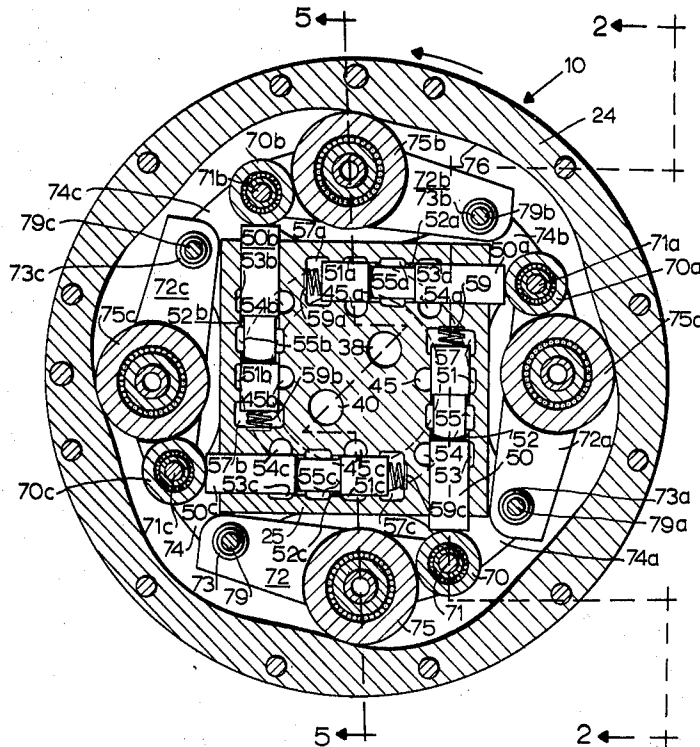
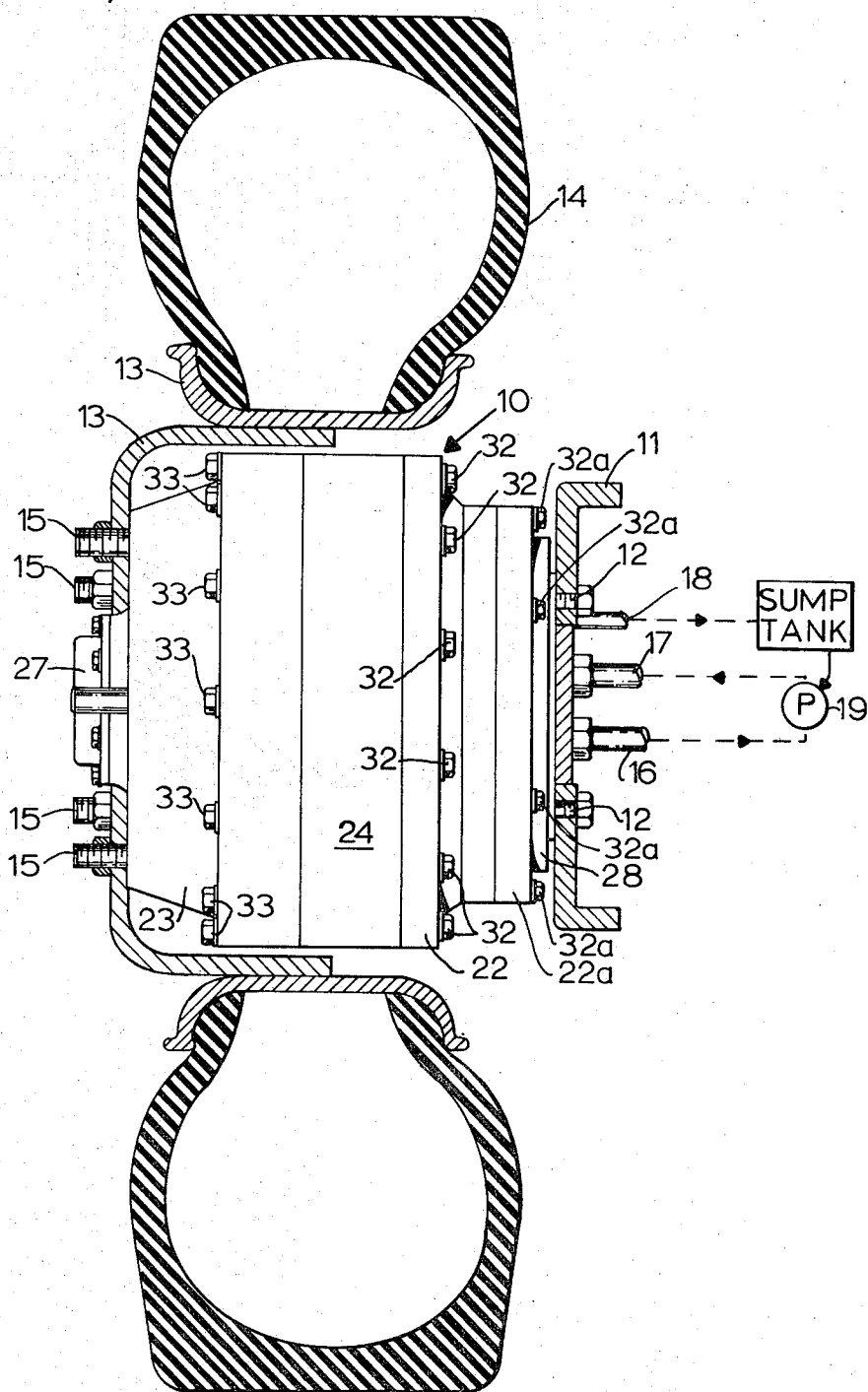


FIG. 1



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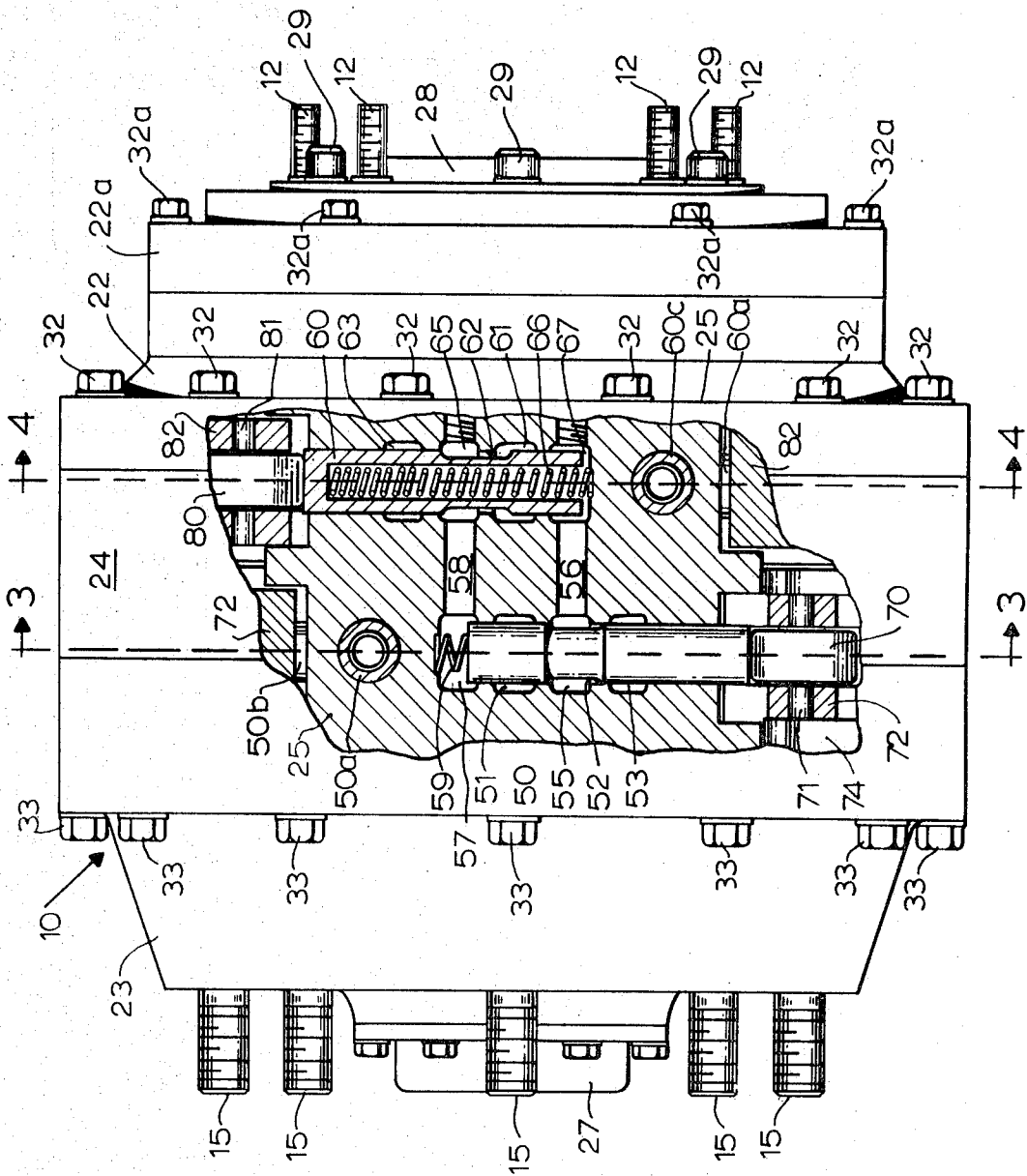
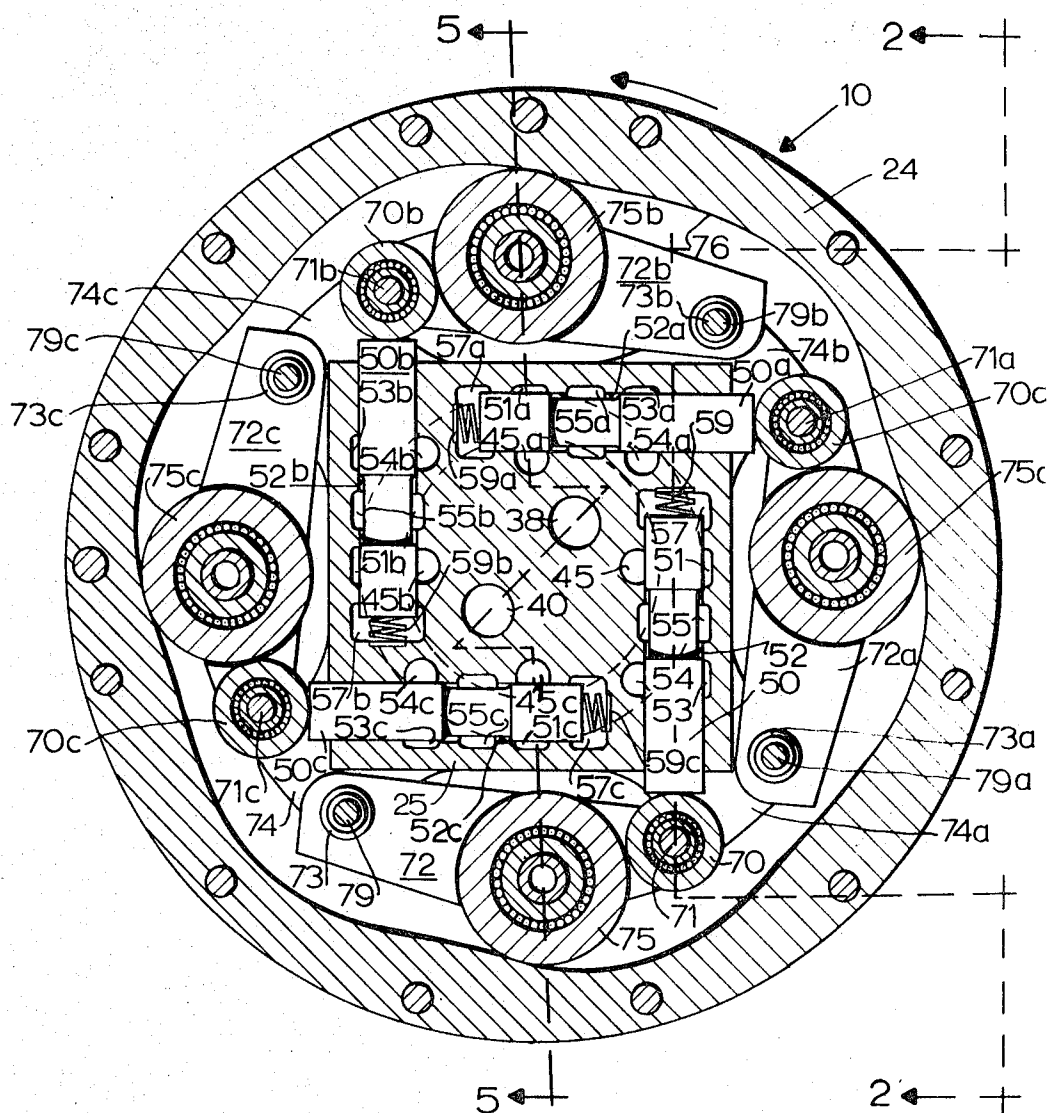


FIG. 2

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FIG. 3

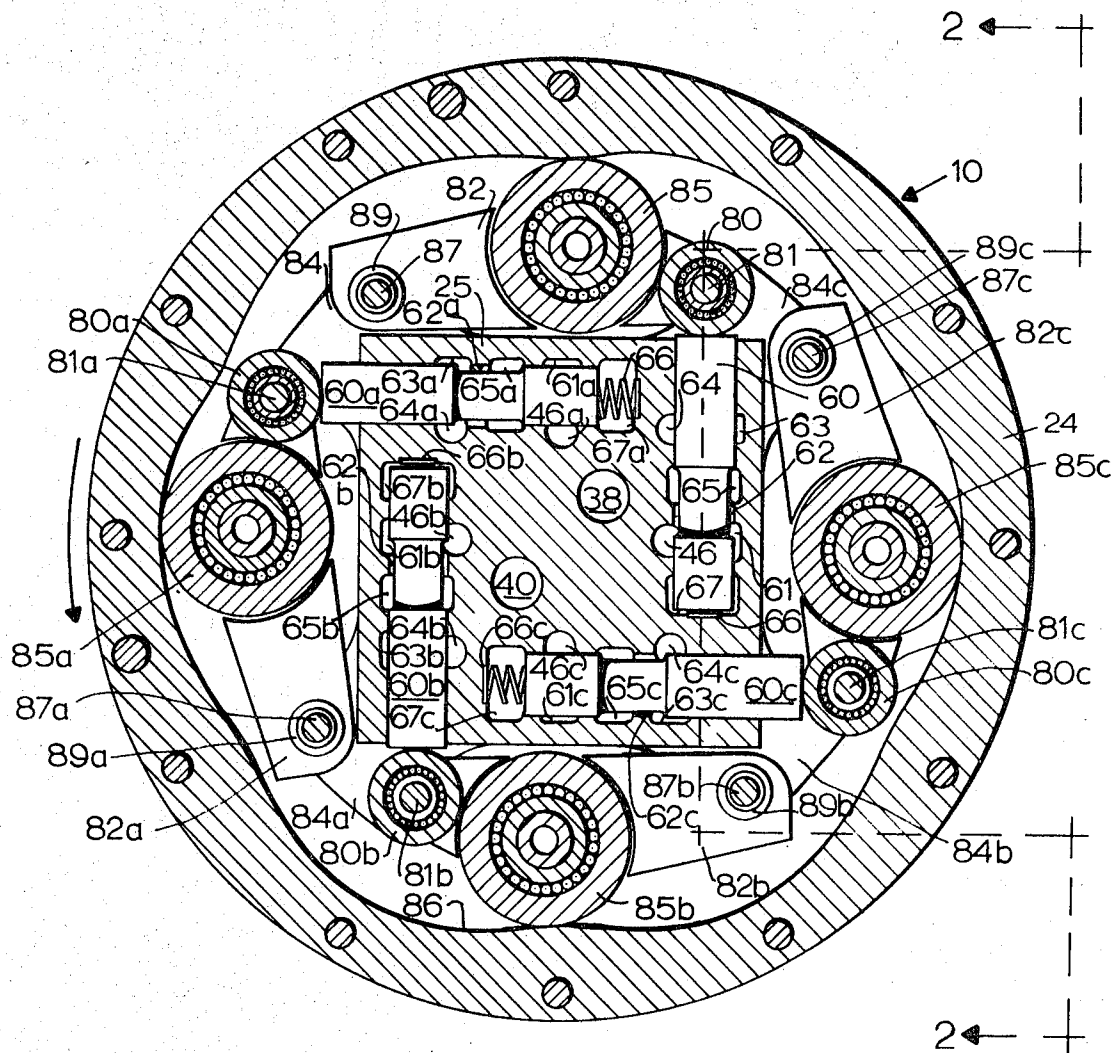


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FIG. 4



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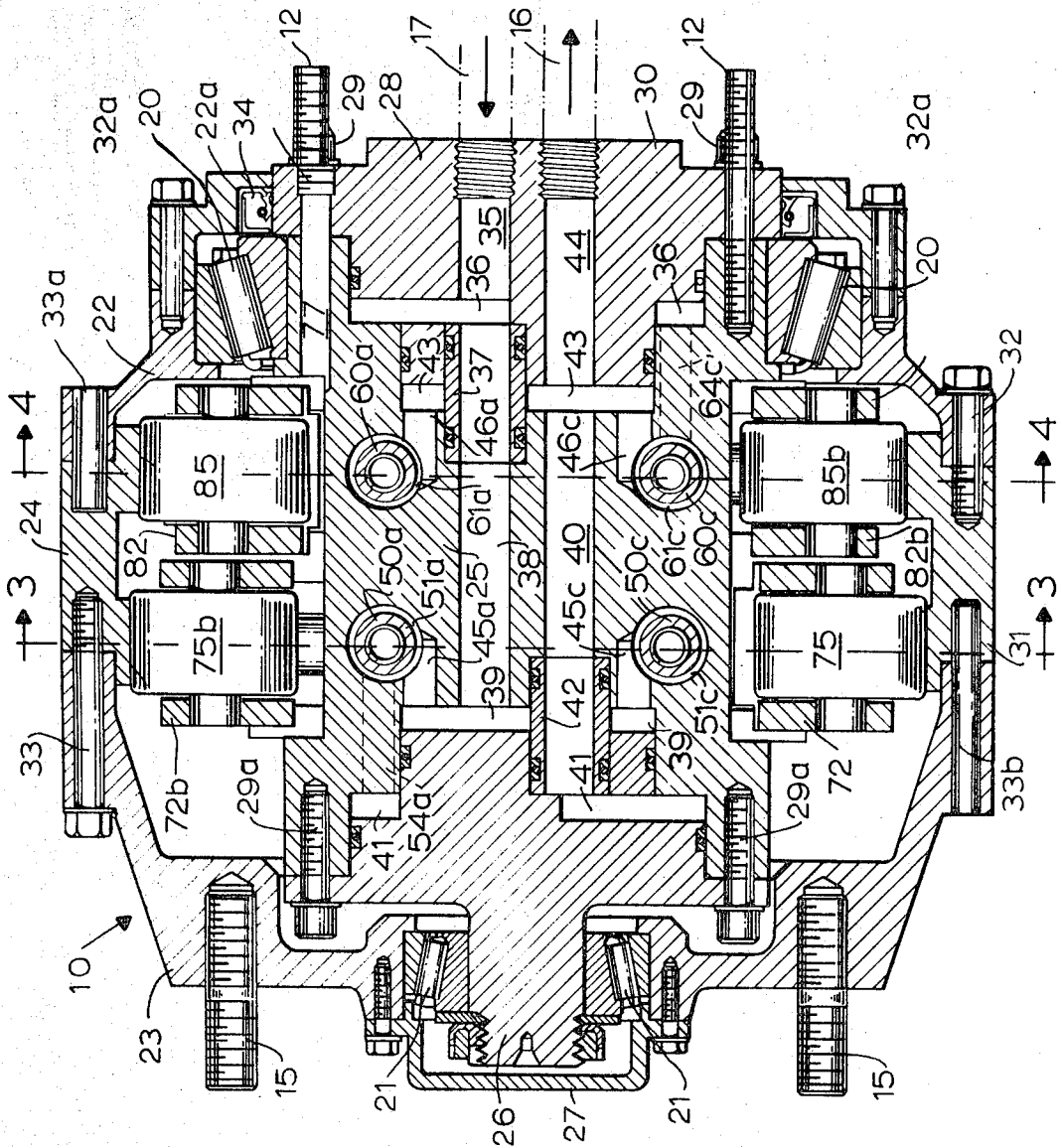


FIG. 5

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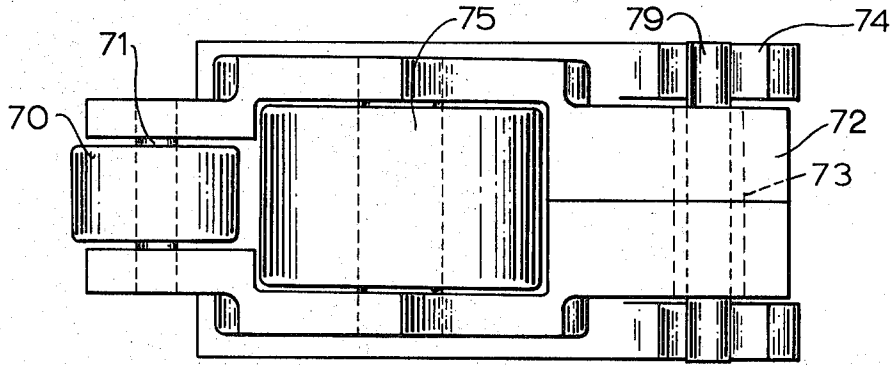


FIG. 6

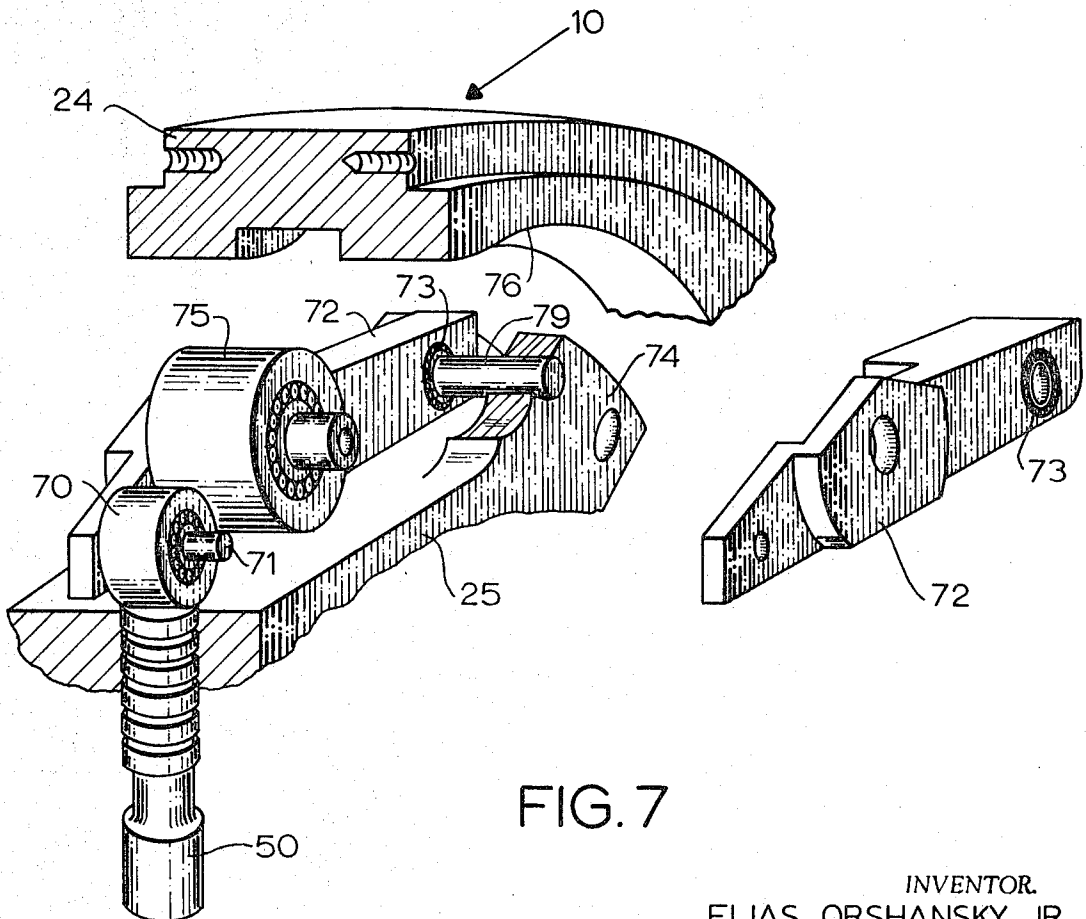


FIG. 7

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FLUID MOTOR

This invention relates to an improved hydraulic cam motor.

Hydraulic pumps and motors have commonly been subject to problems traceable to their valves and pistons and their associated activating mechanisms. Rotating valves, in particular, have been subject to leakage, and to damage from unwanted particles in the hydraulic fluid, which have tended to abrade, score, or bind the valves. Pistons have frequently been subjected to relatively large side loads; the resulting poor lubrication and losses in horsepower have led to severe limitations in useful piston force and speed. Fluid flow through these units has been inherently nonuniform, resulting in pressure or speed fluctuation, or both; such fluctuations usually being undesirable.

Still another trouble with prior art hydraulic motors, particularly when they are to be used in machine tools, has been fluctuations in output torque, causing a speed ripple.

The present invention effectively solves these difficulties and at the same time introduces other improvements, all of which produce much greater efficiency. The invention enables the production of powerful and reliable wheel motors capable of large loads and high horsepowers. It also makes it possible to calculate a cam profile that provides constant torque and speed for a given input.

Other objects and advantages of the invention will appear from the following description of a preferred form thereof.

In the drawings:

FIG. 1 is a view in side elevation and partly in section of a vehicle wheel and a wheel motor embodying the principles of the present invention.

FIG. 2 is a view in elevation partly broken away and shown in section of the wheel motor of FIG. 1, and along the line 2-2 in FIG. 3.

FIG. 3 is a view in section taken along the line 3-3 in FIGS. 2 and 5.

FIG. 4 is a view in section taken along a line 4-4 in FIGS. 2 and 5.

FIG. 5 is a view in section taken along the line 5-5 in FIG. 3.

FIG. 6 is a top plan view of one of the roller cam-link assemblies.

FIG. 7 is a partially exploded fragmentary view in perspective and partly in section of one cam-link roller assembly along with its associated cam track.

A cam motor 10 of this invention is shown in FIG. 1, in use as a wheel motor, with one side fastened to a vehicle frame 11 by bolts 12 and nuts, and to its other side is mounted a conventional wheel and rim 13 which carries a tire 14. The wheel 13 may be fastened to the cam motor 10 by studs 15 and nuts. The motor of this invention can, of course, be used to drive a shaft instead of being used as a wheel motor.

Three hydraulic lines 16, 17, 18, lead to or from the motor 10. The lines 16 and 17 are connected to a pump 19 which supplies the hydraulic pressure; the pump 19 is bidirectional, so that it may supply pressure through the line 16 for rotation of the motor 10 in a first direction, or the direction of flow may be reversed to supply pressure through the line 17, for rotation of the motor 10 in the opposite direction. Whichever line 16 or 17 supplies the fluid to the motor 10, the opposite line 17 or 16 returns the fluid to the pump 19. In addition, the drain line 18 is used to return such fluid as leaks past the pistons into a sump tank, for use by the pump 19.

The wheel motor 10 acts to support the wheel 13 on the frame 11, the motor's bearings 20 and 21 (See FIG. 5) carrying the vehicle weight. Thus, the motor 10 is part of the complete wheel; in fact, the tire 14 might be mounted directly on the motor 10, but for ease of interchangeability the use of a conventional wheel rim 13 may be preferable.

FIGS. 2 to 5 show the cam motor 10 alone, without the wheel 13. FIG. 2, shows in a partial breakaway, two of the eight pistons, one from each of two sets, to illustrate the fact that one set of pistons is valved by the other set, and vice versa, a very important feature of the invention, explained below. FIG. 3 shows one set of four pistons and their linkage, which transmits power to the cam ring, and FIG. 4 shows the other

set of four pistons. Two pistons of each set are shown in FIG. 5, in the planes of lines 3-3 and 4-4, each set having a corresponding cam which appears in full view in FIGS. 3 and 4, respectively.

As shown best in FIGS. 1, 2, and 5, the motor 10 has a housing made up of end members 22, 22a, and 23 and a central annular member 24, which form a rotating outer housing, supported by bearings 20 and 21 on a stationary cylinder block 25 and a stationary outer hub 26. A hub cap 27 protects the bearings 21, while an inner hub 28 is provided radially within the housing member 22a and the cylinder block 25. The hubs 26 and 28 are fastened to the block 25. Thus, the inner hub 28, cylinder block 25, and outer hub 26 form a stationary assembly that is bolted together by cap screws 29 and 29a and is bolted and to the vehicle frame 11 by the studs 12. Suitable nonrotative O-rings or oil seals are provided between the block 25 and the hubs 26 and 28, so that (as shown in FIG. 5) these three members function as a single stationary assembly 30 in the assembled motor 10. Similarly, the rotatable housing members 22, 22a, 23, and 24, and the hub cap 27 form a single rotatable assembly 31 held together by bolts 32, 32a, and 33. Tightly fitting dowels 33a and 33b may be provided for transmitting torque between a cam ring 76 in the member 24 and the covers 22 and 23. The bearings 20 and 21 lie between the stationary assembly 30 and the rotatable assembly 31, or, more specifically, the bearing 20 is between the block 25 and the end housing member 22a and is protected by rotary oil seal 34 between the end housing member 22a and the inner hub 28, while the bearing 21 lies between the outer hub 26 and the end housing member 23 and is protected by the hub cap 27.

Referring to FIG. 5, hydraulic fluid such as oil from the pump 19 and the conduit 17 enters the motor 10 through a passage 35 in the inner hub 28 and flows into a space 36, which lies between the hub 28 and the block 25. Thence, the fluid flows through a ferrule 37 and a passage 38 in the cylinder block 25 and into a space 39 between the outer hub 26 and the block 25. A return passage 40 in the block 25 leads from a space 41 between the hub 26 and the block 25, via a ferrule 42 to a space 43 between the inner hub 28 and the block 25 to a passage 44 in the hub 28 that is connected to the return line 16 to the pump 19. As already mentioned, the flow direction may be reversed for reversing the wheel's direction of rotation.

Thus, there are four spaces filled with oil, two spaces 36, 43 on the right-hand side of the motor 10 (as viewed in FIG. 5) and two spaces 39 and 41 on the left-hand side of the motor 10. If high pressure is supplied through the conduit 17 and passage 35, then the space 36 will be under high pressure, as will the space 39; in that instance, the passage 40 and 44 act as part of the return line 16, and the spaces 41 and 43 are under low pressure.

This motor 10 is characterized by four important features; first, the same part functions both as a valve and a piston: a first series of valve-and-piston members 50, 50a, 50b, and 50c cooperates with a second series of valve-and-piston members 60, 60a, 60b, and 60c, each piston 50, etc., acting as a valve for an adjacent piston 60, etc., and vice versa; second, the pistons 50, 60, transmit their force through respective antifriction rollers 70, 80 without placing any side load on themselves; third, the piston force is finally transmitted to the rotating member 24 by means of rollers 75 or 85; and fourth, the force is transmitted to a multilobe cam 76 or 86 comprising respective surfaces of the member 24, and the number of lobes may be varied to increase or decrease the r.p.m. or speed and inversely to decrease or increase the torque of the motor 10 at a given input of fluid. The number of lobes in each cam 76 or 86 should always be the product of two and an odd number.

Referring to FIGS. 3 and 5, the space 39 is connected by means of passages 45, 45a, 45b, 45c, to respective annular channels 51, 51a, 51b, 51c, respectively. As shown in FIGS. 2 and 3, the channel 51 is a recess from a bore or cylinder 52 in which the valve-piston member 50 reciprocates; spaced away

from the channel 51 toward the other end of the bore 52 is an annular channel 53 that is connected to a drilled passage 54, leading to the space 41. In between the channels 51 and 53 is another annular channel 55 recessed from the bore 52 and joined to a drilled passage 56 shown only in FIG. 2. At the inner end of each bore 52 is an annular channel 57 that is connected to a drilled passage 58, also shown only in FIG. 2. A spring 59 urges the piston 50 outwardly of the bore 52. There are elements corresponding to the elements 52 through 59 for each of the four assemblies, each designated appropriately by the addition of an *a*, *b*, or *c* used for that assembly.

As shown in FIGS. 2, 4, and 5, the valve-piston member 60, is similarly provided with annular channels 61, 63, 65, and 67 corresponding to the channels 51, 53, 55, and 57. There is a bore or cylinder 62, a passage 46 connects the annular channel 61 to the space 43, and a passage 64 connects the channel 63 to the space 36. As shown best in FIG. 2, the passage 56 connects the channel 55 to the channel 67, while the passage 58 connects the channel 57 to the channel 65. A spring 66 urges the valve-piston member 60 outwardly. Again, *a*, *b*, and *c* designations are added to the corresponding elements in the other three assemblies.

Each piston 50 is urged by its spring 59 against a roller 70, which is supported rotatably on a shaft 71 mounted in a swing link 72, (See FIGS. 2, 6, and 7). This link 72 is pivoted on needle bearings 73 around a pin 79 that is supported on a cylinder block extension 74 and carries a rotatably bearinged cam roller 75, which rides on a cam surface 76 formed on the interior surface of the central housing member 24. Similarly, (See FIGS. 2 and 4), the spring 66 urges each piston 60 toward a roller 80 supported by a shaft 81 on a swing link 82; the link 82 is pivoted on needle bearings 89 around a pin 87 that is supported on a cylinder block extension 84 and carries a roller 85 that rides on a cam surface 86, also formed on the interior surface of the central housing member 24. When the oil pressure is supplied to the piston 50 (FIGS. 2 and 3) through the passage 58, the piston 50 is moved outwardly and exerts a force on the roller 70, and when oil pressure is applied to the piston 60 (FIGS. 2 and 4) through the passage 56, the piston 60 is moved outwardly and exerts an actuation force on the roller 80. The purpose of the rollers 70 and 80 is to make it possible for the swing links 72, 82 to reciprocate without placing a side load on the pistons 50, 60. Since the links 72, 82 are each pivoted on needle bearings 73, 89, they swing up and down and transmit their force through the cam roller 75, 85 to the cam ring 76 or 86, all without producing side load on the pistons 50, 60. The phases of the various pistons 50 and 60 are disposed in such a manner that at least two of them are acting at any given moment, so that rotation is continuous.

Furthermore, the eight pistons 50 and 60 act as four pairs, and the resultant force on the cams 76 and 86 balances the loads on the bearings 20 and 21. Therefore, there is no theoretical load on the bearings 20 and 21, which are used mainly to support the weight of the vehicle. However, four pistons would produce a rough type of pumping and a considerable degree of fluctuation of torque if it were not for the fact that the cam tracks 76, 86 are meticulously calculated to provide each piston 50, 60 with such a motion that the sum total of all of these motions results in a constant flow and in constant torque acting upon the tracks 76, 86. The calculation is based on the fact that since two pairs of pistons are discharging at any one time, substantially constant discharge can be obtained by having the sum of the rates of change of displacement of the pistons that are discharging remain substantially constant. It is also desirable to limit the accelerating forces on the swing links 72, 82 to reduce the spring pressure.

The two cam tracks 76, 86 are calculated and spaced to give a phase relation that enables this to be carried out. For example, as illustrated, each cam track 76, 86 has 6 cycles, so that 60° on the track 76 or 86 corresponds to 360° (one complete cycle) for each piston 50 or 60. As seen in FIGS. 3 and 4, the tracks 76, 86 are 15° out of phase, corresponding to 90° of piston cycle. Thus, in FIG. 3, each piston 50, 50a, 50b, and

50c is shown in midstroke where neither the channel 51 nor the channel 53 is contiguous with the channel 55. Simultaneously, (FIG. 4) the piston 60c is at its maximum extension, so that the channel 61 is in communication with the channel 65. At this point, supposing that the valving piston 50c in FIG. 3 is moving to the right, it has just cut off the high-pressure line 54 and is about to open the low pressure line 45. As the piston 60c is driven back into its bore 62 by the cam 86, it discharges hydraulic fluid from the space 67 (See FIG. 2) through the passage 56 into the space 55. The valving piston 50 in FIG. 2 is moving outwardly and is therefore about to open communication between the spaces 55 and 51, thus discharging the oil from the space 67 through the valving portion of the piston 50c into the low-pressure passage 45. For the direction shown by the arrow in FIG. 4, therefore, the passage 45, the space 43 and the passages 44 and 17 are at low pressure and the oil is discharged as shown by the arrows in FIG. 5. The piston 50c is also under pressure supplied to it through the passage 58, which is connected to the high pressure via the channel 61 associated with the piston 60 and the passage 46. Consequently, the spaces 39 and 36 to which the passage 46 is connected (See FIG. 5) is under high pressure, and the spaces 41 and 43 are under low pressure.

Leakage from a high pressure passage, for instance the passage 45, goes directly either to the passage 56 or past the piston 50 into the space surrounding the cylinder block and contained by the case of the transmission. It is necessary to remove this leakage to the sump tank, and this is done by means of a passage 77, shown in FIG. 5, which has a threaded portion into which fits the drain line 18 that returns the leakage to the sump tank (See FIG. 1). Therefore, the entire space inside the motor 10 is at all times filled with oil (hydraulic fluid), but not all of this is under pressure. Since the entire outer case 22, 23, and 24 of the motor 10 rotates, the seal 34, (FIG. 5) acts to prevent leakage between the rotating outer end housing member 22 of the motor 11 and the stationary inner hub 28, but the seal 34 is never under substantial pressure because the oil that it seals is always substantially at atmospheric pressure.

This motor 10 possesses many advantages. One advantage is that the valving is accomplished by the spool section of each piston 50, 60 when it acts as a valve for the next piston 60, 50. This is extremely desirable, because there is more trouble in hydraulic pumps and motors from rotating valves moving at rapid velocity than from any other single source of trouble, and the piston-type valve of this invention is not only more efficient but is very much more resistant to dirt, is not as likely to abrade or score, and is not as likely to bind as is a pintle type rotating valve.

Another major source of hydraulic motor trouble which does not exist in the motor 10, is piston side load which, particularly in large units, results in very considerable side forces under poor conditions of lubrication, and therefore results in limitation of speeds and loads which can be tolerated. In this motor 10, there is no piston side load because the pistons 50, 60 react on the rollers 70, 80, which roll slightly to remove any side friction from the piston connection. The torque reaction is taken by the needle bearings 73, 89 at the pivot of the swing link 72, 82, the most efficient manner of taking such a reaction.

The fact that there are four pairs of pistons 50, 60 and that the pistons of each pair 50, 60 or 50a, 60a, or 50b, 60b, or 50c, 60c, also operate in opposite direction, balances out the forces on the support bearings 20, 21 and therefore results in very high efficiency.

The passages for valving can be made relatively large and the oil velocities low, and this also contributes to improved efficiency.

Additionally, the fact that the pistons 50, 60 in the two rows move in opposite directions and so do their associated links 72, 82 also balances the reciprocating masses within the unit and it is therefore free of vibration. Furthermore, the shape of the cam 76, 86, which is calculated to produce constant dis-

placement and constant torque, provides for extremely smooth operation. Because the motor operates solely on rolling contact transfer of forces, it exerts a static torque almost identical to its running torque, and its torque and leakage efficiency therefore are very high.

Additionally, there are only eight major part types in this motor, so that it is simple and inexpensive to make and maintain. The motor bearings are used to support the weight of the vehicle. The dimensions of the motor are small and it fits within the confines of a conventional duotire wheel or large width tire.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

I claim:

1. A fluid motor, including in combination:
 - a stationary body having first and second sets of cylinders, each cylinder in said first set being paired to a cylinder in said second set, each cylinder being open at one end and having an actuation chamber at the other end and having, in between the ends, a valving recess in between an inlet recess and an outlet recess, said body having inlet passage means leading to each said inlet recess and outlet passage means leading to each said outlet recess, each of the paired cylinders having its valving recess connected to the actuation chamber of the other cylinder of the pair;
 - first and second sets of pistons corresponding to the cylinder sets, there being a piston in each said cylinder having an inner end facing said actuation chamber and an outer end and recessed in between its ends so as to valve fluid between said valving recess and said inlet and outlet recesses, whereby each piston serves as a valve for its paired piston;
 - means for urging said piston normally outwardly;
 - a rotatable housing rotatably mounted on said body; and
 - means for transmitting the outward movement of each said piston to said rotatable housing for rotation of said housing about said body.
2. The fluid motor of claim 1 wherein said means for transmitting comprises:
 - first and second internal circumferential cam rings mounted in said housing;
 - means for transmitting the outward movement of each piston of said first set to said first cam ring; and
 - means for transmitting the outward movement of each piston of said second set to said second cam ring.
3. The fluid motor of claim 1 wherein said means for transmitting comprises:
 - a link associated with each piston and pivotally mounted to said body, each link having a piston-engaging roller mounted thereon and in contact with the outer end of its associated said piston, each link also having a cam roller mounted thereon; and
 - two internal circumferential cam rings in said housing and secured thereto, the first said cam ring being in contact with the cam rollers for said first set of pistons, the second said cam ring being in contact with the cam rollers for said second set of pistons.
4. The fluid motor of claim 1 wherein each set of cylinders is arranged so that their axes are tangent to a single circle made up of diametrically opposite pairs of cylinders and said cams are patterned so that the pistons in each said diametrically opposite pair are in phase with each other.
5. The fluid motor of claim 4 wherein each said cam has a number of lobes equal to twice an odd number.
6. The fluid motor of claim 4 wherein each set of cylinders consists of four cylinders located 90° apart and with the axis of each at right angles to the axes of the two adjacent cylinders, each pair of paired cylinders having their axes parallel to each other and with their pistons facing in opposite directions.

7. The fluid motor of claim 6 wherein each cam has six lobes evenly spaced therearound.

8. The fluid motor of claim 4 wherein each cam is shaped to provide constant torque and constant fluid flow rate during uniform rotational velocity of said rotating assembly.

9. The fluid motor of claim 1 having:

fluid pressure means; and

means for connecting said fluid pressure means at one time to said inlet passage means for said first set and at another time to said inlet passage means for said second set, thereby enabling said fluid motor to run in both directions.

10. A fluid motor, including in combination:

a stationary body having first and second sets of cylinders therein, said sets lying with the axes of each set in a plane and the planes of the two sets parallel to each other, each cylinder in said first set being paired to a cylinder in said second set, each cylinder being open at one end and having an actuation chamber at the other end and having, recessed into said body, first, second, and third annular recesses, around and communicating with the cylinder and spaced apart axially and sequentially from said actuation chamber toward said open end, said body having passage means providing fluid inlet means for each said first recess and fluid outlet means for each said third recess, the second recess of each cylinder in said first set being connected by a passage in said body to the actuation chamber of its paired cylinder in said second set, the actuation cylinder of the same cylinder in said first set being connected by a passage in said body to the second recess of the same paired cylinder in said second set;

a piston in each said cylinder, so that there are first and second sets of pistons corresponding to the first and second sets of cylinders, each piston having an inner end facing said actuation chamber and an outer end having a recessed portion in between its ends serving, with the unrecessed remainder of said piston, as a valve to connect and disconnect said second recess to each of said first and third recesses, depending on the axial position of said piston in its cylinder, so that each cylinder and piston in said first set serves as a valve for its paired cylinder and piston in the second set and is valved by that same paired cylinder and piston;

spring means urging each said piston normally outwardly;

a link associated with each piston and pivotally mounted to said body, each link having a piston-engaging roller mounted thereon and in contact with the outer end of its associated said piston, each link also having a cam roller mounted thereon; and

a rotatable housing rotatably mounted on said body and having two internal circumferential cam rings, the first said cam ring being in contact with the cam rollers for said first set of pistons, the second said cam ring being in contact with the cam rollers for said second set of pistons.

11. The fluid motor of claim 10 wherein each set of cylinders is arranged so that their axes are tangent to a single circle made up of diametrically opposite pairs of cylinders and said cams are patterned so that the pistons in each said diametrically opposite pair are in the same phase with each other.

12. The fluid motor of claim 11 wherein each said cam has a number of lobes equal to twice an odd number.

13. The fluid motor of claim 11 wherein each set of cylinders consists of four cylinders located 90° apart and with the axis of each at right angles to the axes of the two adjacent cylinders, each pair of paired cylinders having their axes parallel to each other and with their pistons facing in opposite directions.

14. The fluid motor of claim 13 wherein each cam has six lobes evenly spaced therearound.

15. The fluid motor of claim 10 wherein each cam is shaped to provide constant torque and constant fluid flow rate during uniform rotational velocity of said rotating assembly.