Fig. 2

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This invention relates to a rotary fluid motor or pump mechanism and is more particularly described in connection with the propulsion and braking of automotive vehicles although features of the invention can be employed in a wide variety of other uses.

One of the principal objects of the invention is to provide a rotary fluid motor or pump mechanism which is highly efficient in the forward and reverse transmission of power and also in the propagation and absorption of energy in braking.

Another object is to provide such a mechanism in which the fluid generator and motor units are very compact and which, in particular, the units can be built into the wheel of a small pleasure automobile.

Another object is to provide such a mechanism in which the fluid motor and generator units can be arranged at a distance from one another and in which the fluid motor or fluid generator can readily be built in tandem to suit the particular power conditions involved.

Another object is to provide such a mechanism which is readily controlled with limited manual effort and in which any desired change in ratio between the engine speed and vehicle or wheel speed of an automotive vehicle can be obtained.

Another object is to provide such a mechanism in which a plurality of fluid generators are employed and in which automatic control is provided to cut different numbers of such fluid generators into and out of operation in accordance with the power and speed demands.

Another object is to provide such a mechanism which is applicable to light and heavily loaded vehicles and which is applicable to slow and high speed vehicles.

Another object is to provide such a mechanism which is particularly applicable to tandem axle vehicles.

Another object is to provide such a mechanism which is light in weight, particularly the fluid generator and motor units of the mechanism which are designed to be incorporated as a part of the unsprung weight of the vehicle.

Another object is to provide such a mechanism employing separate fluid motor and generator units for the several wheels of an automotive vehicle and from which each wheel receives power equal to its companion wheel and in proportion to the weight it carries relative to the wheels on the other axles.

Another object is to provide, in such a mechanism, a metering device which prevents any wheel from rotating more than a certain degree faster than the other wheels thereby to prevent the vehicle from being rendered immobile because of the free rotation of any one of its driving wheels.

Another object is to provide such a mechanism which eliminates the necessity for a differential.

Another object is to provide such a mechanism which eliminates the necessity for a friction braking system.

Another object is to provide such a mechanism in which relatively sliding parts are provided with a protecting film of oil at all times, thereby to avoid wear even when, as in continued braking, a heavy load is imposed on the mechanism for a protracted period of time.

Another object is to provide such a mechanism in which the fluid generator and motor units are instantaneously and automatically reversible.

Another object is to provide such a mechanism which is completely flexible for application to all types of vehicle engines and in particular is adaptable to single and tandem axle pleasure cars, buses, trucks, trailers and railroad cars.

Another object is to provide, in such a mechanism, a fluid motor and generator unit in which all parts can be readily and economically brought to micro-tolerances, this being accomplished by machining the housing and working parts assembled therein in a single operation and thereafter fitting an accurately machined cover plate or the like over the machined assembly.

Another object is to provide in such a mechanism, a radially movable vane type of fluid motor and generator unit, in which each vane is held against the wall of its working chamber by sufficient fluid pressure to prevent leakage and insufficient to break down the oil film between such vane and wall.

Another object is to provide, in such a mechanism, a radially movable vane type of fluid motor and generator unit in which a simple and effective contact shoe is provided at the outer end of each vane which engages and conforms to the wall of the working chamber and which cannot become displaced from the vane.

Another object is to provide a radially movable vane type of fluid motor and generator unit
in which the fluid is adequately sealed against escape.

The objects and advantages of the invention will appear from the following description and drawings in which:

Fig. 1 is a diagrammatical representation of a fluid drive and brake system embodying the present invention and applied to a four-wheel automobile vehicle. The lines which are shown as stippled represent the high pressure side of the system when the vehicle is moving forwardly at low speed, and the lines which are not stippled represent the low pressure side of the system under these conditions.

Fig. 2 is a vertical axial section through one of the front steering wheels of the vehicle and showing the same equipped with a fluid motor and generator unit embodying the present invention, this section being taken on line 2-2, Fig. 3.

Fig. 3 is a vertical transverse section taken on line 3-3, Fig. 2.

Fig. 4 is a side elevation of the lotted disk used in the fluid motor and generator unit illustrated in detail in Figs. 2 and 3.

Fig. 5 is a fragmentary transverse sectional view through the outer end of one of the vanes used in conjunction with the lotted disk shown in Fig. 4.

Fig. 6 is a vertical longitudinal section through the multiple or tandem motor and generator unit shown in Fig. 1 as connected with the drive shaft of the vehicle engine.

Fig. 7 is a fragmentary vertical section taken on line 7-7, Fig. 1.

Fig. 8 is a vertical section taken on line 8-8, Fig. 7.

Fig. 9 is a fragmentary section similar to Fig. 2 and showing a modified form of motor and generator unit.

The fluid drive and brake mechanism includes a plurality of fluid generator and motor units which are identical in general design and some of which are mechanically connected with the engine or prime mover of the vehicle and others of which are mechanically connected with the wheels of the vehicle, the units being interconnected by fluid transmission lines which include the necessary valves, metering devices, by-passes and other apparatus to provide in each unit the required condition under which these units be simple, durable, free from adjustment and misadjustment, difficulties and efficient in power transmission, it is essential that these units be completely automatic in four ways:

1. Each unit, when used as a fluid generator or pump, must be capable of instantaneously becoming a fluid motor if fluid or oil is fed to either of its ports under preponderating pressure.

2. Conversely, each unit, when used as a motor, must be capable of instantaneously becoming a fluid generator or pump if power is mechanically applied to its shaft in either direction.

3. Each unit, when used as a fluid generator, or pump must be automatically and instantaneously reversible.

4. Each unit, when used as a motor must also be automatically and instantaneously reversible.

To this end each motor and generator unit as shown in detail in Figs. 2-5 comprises a circular housing 10 of relatively large diameter having a flat, axially extending face 11 against which is fitted the flat, axially extending face 12 of a cover plate 13 by means of an annular series of bolts 14 or in any other suitable manner. The housing 10 is formed to provide a relatively shallow cylindrical chamber 15 having an inner radially extending flat face 16 and a shallow cylindrical face 18, the other face of this chamber being formed by the flat, radially extending face 12 of the cover plate 13. The housing 10 is also recessed to provide a central cylindrical chamber 19 extending from the flat, radially extending face 16 of the cylindrical chamber 15 and of substantially smaller diameter than the cylindrical chamber 15. The cover plate 13 is recessed to provide a central cylindrical chamber 20 in opposed relation to and of generally the same diameter as the central cylindrical chamber 19 of the housing 10. The circular housing 10 is formed to provide a hub 21 containing a roller bearing 22 which is in eccentric relation to the cylindrical chamber 15 and the cover plate 13 is formed to provide a hub 23 containing a roller bearing 24 which is concentric with the roller bearing 22. The hub 23 also contains an annular oil seal 25 in its outer extent, these vanes being interposed between a hollow shaft 26 having an enlarged part 28, journaled in roller bearing 24 and a reduced end 29 journaled in the roller bearing 22. The portion of this hollow shaft 26 intermediate its bearing portions 28 and 29 is formed to provide a series of equidistant spaces 30 on which the splined hub of a cylindrical disk 31 is mounted, this disk 31 being thereby capable of axial movement on the hollow shaft 26 but being compelled to rotate therewith. This disk 31 is provided with opposite, flat, radially extending faces closely fitting the flat, radially extending faces 12 and 16 of the cover plate 13 and housing 10, respectively, and its peripheral face is concentric with the hollow shaft 26 and hence in eccentric relation to the cylindrical face 18 of the cylindrical chamber 15.

The disk is provided with a plurality of slots 32 which are rectangular in cross section and which extend radially inwardly from its periphery at spaced intervals. In each of these slots is slidingly mounted a vane 33 which is rectangular in cross section, the faces of each of these vanes being parallel and flat and one pair of these faces closely fitting the flat, radially extending faces 12 and 16 of the cover plate 13 and housing 10, respectively, and the other pair closely fitting the parallel sides of the slots 32 in the disk 31. Each of these vanes 33 is biased radially outwardly by a helical compression spring 34, the outer end of each of these springs being secured in a bore 35 provided lengthwise in the companion vane 33 from the inner end thereof, and the inner end of each of these compression springs 34 being sealed in a companion socket 36 provided in the hub of the lotted disk 31 which carries the vanes 33.

The outer end of each of the vanes 33 is formed to provide a semi-cylindrical socket 38 which extends parallel with the axes of the hollow shaft 26 and housing 10. A semi-cylindrical shoe 39 is fitted in each of these sockets, the flat ends of these shoes engaging the radially extending flat faces 12 and 16 of the cover plate 13 and housing 10, respectively, and the outer side faces 40 of these shoes being formed with a flattened curved surface to conform to the peripheral face 18 of the cylindrical chamber 15. In order to prevent separation of these shoes 39 from the vanes 33, the sides of the semi-cylindrical sockets 38 are extended to form lips 42 which extend beyond a plane intersecting the axis of the shoe 39 and provide with an arcuate slot 43 which receives a pin 44 projecting into the socket 38 from the vane 33. These pins prevent the shoes 39 from sliding endwise out of the sockets 38 when the
vanes 33 are removed from the motor and generator housing.

A pair of generally flat rings 45 and 46 are secured to the disk 31 in concentric relation therewith, these rings being on opposite sides of the disk and secured by two annular series of bolts 48 which extend through holes provided in the rings 45 and 46 and disk 31 and securely clamp these rings to the opposite side faces of the disk 31. The ring 45 is provided with an annular channel 49 on the side engaging the disk 31 and the other ring 46 is provided with a similar channel 50 which registers with the channel 49 and is also provided on the side of the ring 46 engaging the disk 31. These channels 49 and 50 also register and are in communication with the inner ends of the slots 32 so as to place the inner ends of these slots in communication with each other but to isolate the inner ends of these slots from the cylindrical chamber 15.

At intervals the disk 31 is provided with radial bores 52, the inner ends of which are placed in communication with the annular channels 49, 50 of the rings 45, 46 by cross bores 53. The outer end of each of these radial bores 52 is enlarged and threaded to receive the threaded plug 54 which forms the seat for the ball 55 of a check valve 56, the plug 54 being provided with a through bore and an annular seat against which the ball 55 is biased by a helical compression spring 58 in the enlarged outer end of the bore 52.

It will be seen that the eccentric disk 31 forms with the housing 10 and cover plate 13 a C-shaped working chamber 60 which is divided into segments by the radially movable vanes 31. Oil or other fluid is introduced to or removed from opposite ends of this working chamber through elongated arcuate ports 61, 61', these ports communicate with arcuate passages 62, 62' which lead to threaded bosses 63, 63' to which the lines connecting the motor and generator units are attached.

It will also be seen from an inspection of Fig. 2 that the arcuate passages 62, 62' conform with the arcuate ports 61, 61' and are disposed radially inwardly therefrom to provide outwardly projecting arcuate walls 64 in the housing 10 defined by the arcuate passages 62, 62', arcuate ports 61, 61', and cylindrical chamber 15. These arcuate walls are comparatively thin and hence deflectable laterally by high fluid pressure in either of the arcuate passages 62, 62'. Hence when either of these arcuate passages are on the high pressure side of the system, the corresponding arcuate wall 64 is deflected laterally toward the disk 31 so as to insure pressure tight fit of this disk against the faces 12 and 16 of its cylindrical chamber 15 on its high pressure side. It will be understood that this deflection of the arcuate walls 64 is microscopic, all tolerances between the disk 31 and its enclosing housing, including the cover plate 13, being slight.

At each wheel the motor and generator unit is securely mounted in the frame and for this purpose each wheel spindle is shown as being in the form of a rod 65 extending through the hollow shaft 26 of the motor and generator unit and as having its inner end welded, as indicated at 66, to an annular supporting plate or disk 68 which is connected through a spring suspension 30 to the vehicle chassis. In the case of the front steering wheels this connection is through the usual king pins 69 to the front axle (not shown) and in the case of the rear wheels this connection is directly to the rear axle (not shown). Each supporting plate or disk 68, near its periphery and on the side facing the motor and generator unit, is recessed, as indicated at 70 to receive an axially extending annular rib 71 provided on the housing 10 and to which the supporting disk 68 is secured by an annular series of screws 72. An oil tight joint is thereby provided between the housing 10 and supporting disk 68.

The outer end of the spindle 65 is threaded to receive a wheel retaining nut 73 and lock nut 74. The retaining nut is formed integrally with a thrust ring 75 which in turn bears against the end of the hollow shaft 26 so as to rotate the shaft 26 in the bearings 22, 24 against the supporting disk 68. The outer end of the hollow shaft 26 is enlarged, as indicated at 76, and formed to provide a cylindrical socket 78. In this socket is arranged an annular oil seal 79 of any suitable form, this oil seal engaging the periphery of the ring 75 to prevent the escape of oil therearound.

The end enlargement 76 of the hollow shaft 26 is also provided with a radially extending flange 80 carrying an annular series of axially extending stud bolts 81. To these stud bolts 81 is secured a wheel disk 82 by the usual nuts 83, the wheel disk having a wheel rim 84 secured to its periphery. The usual removable hub cap 85 can be provided to enclose the otherwise exposed nuts and oil seal 79 at the center of the wheel.

It will be apparent that the motor and generator unit as above described can be built in tandem, this being particularly desirable with the unit connected with the drive shaft 99 of the engine or prime mover 51 of the vehicle, this connection being shown as through a flexible coupling 52.

As best shown in Figs. 1 and 6, this multiple or tandem motor and generator unit is shown as comprising a central cylindrical housing 10a having on each side a flange 2a, radially extending face 11 corresponding to the similar face 11 in the form of unit shown in detail in Figs. 2-5 and against each of which faces 11 is fitted the flange, radially extending face 12 of a plate or disk 13a corresponding to the cover plate 13 in the form of the invention shown in Figs. 2-5. The housing 10a is recessed on opposite sides to provide a relatively shallow cylindrical chamber 15a on each side, each having an inner radially extending flat face 16 and a shallow cylindrical face 18, the other face of each cylindrical chamber being formed by the flange, radially extending face 12 of the corresponding plate or disk 13a. The housing is also recessed to provide a pair of central cylindrical chambers 19 each extending from the corresponding flat, radially extending face 16 of each chamber 15. Each plate or disk 13a is provided with a central bore 20 in opposed relation to and of the same diameter as the central cylindrical chambers 19 of the housing 10a. The housing 10a is formed to provide a central hub 21a containing a roller bearing 22a which is in eccentric relation to the cylindrical chambers 15. In this roller bearing 22a is journaled a shaft 25a corresponding to the hollow shaft 25 in the form of the invention shown in Figs. 2-5. As with the form of the invention shown in Figs. 2-5, this shaft 25a has keys thereto a pair or disks 31a, each disk being arranged in the corresponding cylindrical chamber 15a and being provided with opposite, flat, radially extending faces closely fitting the flat.
radially extending faces 12 and 16 of the corresponding disk or plate 3a and housing 10a, respectively, and its peripheral face being concentric with the shaft 26a and hence in eccentric relation to the cylindrical face 18 of its cylindrical chamber 15.

Each disk 31 in the housing 10a is identical to the disk 31 in the form of the invention shown in Figs. 2-5 and is provided with vanes 33, operating and constructed in the same manner as in the form of the invention shown in Figs. 2-5. Accordingly, a detailed description of these disks 31 is not repeated. Also, as with the form of the invention shown in Figs. 2-5, the eccentricity of the disk 31 with reference to the cylindrical chambers 15 provides a C-shaped working chamber 60 divided into segments by the radially movable vanes 33. Oil or other working fluid is introduced or removed from opposite ends of this C-shaped working chamber through elongated arcuate ports 51, 51'. These ports communicate with arcuate passageways 62, 62' in the housing 10a and which lead to threaded bosses 63, 63' to which the lines connecting the various motor and generator units are attached.

The multiple or tandem motor and generator unit shown in Figs. 1 and 6 also include end housings 16b each having, as with the housing 10 for the individual motor and generator unit, a flat axially extending face 11 which is fitted against the flat, radially extending outer face 12 of the corresponding disk or plate 13a. Each housing 16b is recessed to provide a relatively shallow cylindrical chamber 15 having an inner, radially extending flat face 16 and a shallow cylindrical face 18, the other face of the cylindrical chamber 15 being formed by the outer flat, radially extending face 12 of the disk or plate 13a. Each housing 16b is also recessed to provide a central cylindrical chamber 19 extending from the flat, radially extending face 16 of the chamber 15.

Each housing 16b is formed to provide a hub 21b containing a roller bearing 22b which is eccentric relation to the cylindrical chamber 15. The shaft 23a is journaled in these roller bearings 22b as well as in the central roller bearing 22c.

This shaft has keyed thereto an additional pair of disks 31, each disk being arranged in the corresponding end cylindrical chamber 15 and being provided with opposite, flat radially extending faces closely fitting the flat, radially extending faces 12 and 16 of the corresponding disk or plate 13a and housing 10b, respectively, and its peripheral face being concentric with the shaft 26a and hence in eccentric relation to the cylindrical face 18 of its cylindrical chamber 15.

Each end disk 31 in the housing 10b is identical to the disk 31 in the form of the invention shown in Figs. 2-5, and is provided with vanes 33 operating and constructed in the same manner as in the form of the invention shown in Figs. 2-5. Accordingly, a detailed description of these disks 31 is not repeated. Also as with the form of the invention shown in Figs. 2-5, the eccentricity of each end disk 31 with reference to the cylindrical chamber 15 in the housing 10b provides a C-shaped working chamber 60 divided into segments by the radially movable vanes 33. Oil or other working fluid is introduced to or removed from opposite ends of this C-shaped working chamber through elongated arcuate
2,650,578 gears 113, these working chambers 115 are in communication with each other through an opening 20 provided through the partition 108. On this side the casing 109 is provided with a pair of threaded bosses 121, one of which, however, is plugged with a screw plug 122 and into the other of which a line 123 is screwed, this line 123 connecting the equalizing device 106 as described can lead separately to a third equalizing device 108 and the other side of this third equalizing device 106 can connect with the line 124. This modification of the invention is illustrated by dotted lines in Fig. 1.

Referring again to the diagrammatic representation of the control system shown in Fig. 1, the numeral 130 represents one side of this control system and the numeral 131 represents the other side thereof, this latter side also containing a reservoir 132 having an air head 133 which compensates for the expansion of the oil or other working fluid and also serves to cool the working liquid passing therethrough. For such cooling the reservoir 132 preferably has a central partition 134 which forms a dam or weir to insure circumscribed movement of the oil or other working liquid through the reservoir. However, the two pipes constituting the side 130 of the line connect with this reservoir 132 on the same side of the partition 134 so that fluid flowing the full length of the side 131 is not subject to the impedance provided by this partition.

The side 131 of the control system is also directly connected through branch lines 135 with each of the bosses 63' of the motor generator units D, E, F and G.

The side 130 of the control system is connected by a line 169 with the line 103, this line containing a reversing valve 165 having an actuating arm 170. Similarly, the reservoir 132 connected with the side 131 of the control system is connected by a line 171 with the line 103, this line 171 containing a shut-off valve 172 having an actuating arm 173, this valve 172 being shown in its open position. The arms 165 and 173 of the shut-off valves 165 and 172, respectively, are interconnected by a line 176 to work in opposition to each other, that is, are interconnected so that when the shut-off valve 165 is closed, as shown, the shut-off valve 172 is open. Similarly, the arms 162 and 170 of the reversing valves 161 and 169, respectively, are interconnected by a control rod 176 to work in opposition to each other, that is, are connected so that when the reversing valve 161 is moved to its open position shown, the reversing valve 169 is moved to its closed position shown. This rod 176 is manually operated, as by a small hand reversing lever (not shown) on the steering wheel of the vehicle.

In addition, the arm 162 of the reversing valve 161 and the arm 166 of the shut-off valve 165 are interconnected by a lever 178 pivoted to a stationary part at 179 so as to work in opposition to each other, that is, as the reversing valve 161 is moved to the open position shown, the shut-off valve 165 is moved to its closed position shown. It will therefore be seen that the manual operation of the reversing rod 176 in one direction operates to close the reversing valve 169, open the reversing valve 161, close the shut-off valve 165 and open the shut-off valve 172 and that manual movement of the reversing rod 176 in the opposite direction serves to open the reversing valve 169, close the reversing valve 161, open the shut-off valve 165 and close the shut-off valve 172.

The line 103 contains a brake valve 180 having
an operating lever 181. Similarly, the line 124 contains a brake valve 182 having an operating lever 183. Braking levers 181 and 183 are interconnected by a brake rod 184 so that the valves 180 and 182 open and close together, that is, when the brake valve 180 is moved toward its open position shown, the brake valve 182 likewise moves toward its open position. This is provided in the line 103 around the control or brake valve 180, this bypass containing a check valve 186 which opens toward the line 101. Similarly, a by-pass 188 is provided in the line 124 around the control or brake valve 182, this by-pass containing a check valve 189 which opens toward the line 179.

Where a heavy load is carried by any one wheel, it is desirable to have a wheel motor and generator unit which is of larger capacity and such larger capacity can readily be obtained by providing in the disk 75 and vanes 33 of greater axial size. With such a unit it is necessary to admit and relieve the oil in sufficient volume to permit the larger vanes and disk to rotate at high speed. Under such conditions the form of fluid motor and generator unit shown in Fig. 1 is employed, this having a pair of housings 10h which are identical to the housings 10 in the form of motor and generator unit shown in Figs. 2-5, except that the face 16 of the cylindrical chamber 15 is continued to the periphery of the unit. These two housings are held in spaced relation by a ring 199 which forms the peripheral face 18 of the cylindrical chamber 15. This ring is of substantially the same axial extent as the disk 31h within the chamber 15, this disk being the same as the disk 31 of the form of the invention shown in Figs. 2-5, except that it is of greater axial extent. The housings 10h are secured to the sides of the ring 199 by an annular series of bolts 191 or in any other suitable manner. Each housing 10h contains an arcuate port 61 leading to an arcuate passage 62 in the same manner as in the form of motor and generator unit shown in Figs. 2-5, similar arcuate ports and passages (not shown) being provided at the opposite end of the C-shaped working chamber 60. It will be seen that the form of invention shown in Fig. 9 operates in the same manner as the fluid motor and generator unit shown in Figs. 2-5 except that two passages 62 and ports 61 are provided so that the oil or other working liquid can be introduced into and removed from cooperative relation with the disk 31h and its vanes 33h with greater facility.

It will be seen that the fluid drive and brake mechanism forming the subject of the present invention is designed to replace the present admitted clumsy, noisy and inefficient shaft and gear mechanical drives for automotive vehicles and which are particularly so when more than two wheels of the vehicle are drive wheels. When more than two wheels are driven by shaft and gear mechanical connections with the engine of the vehicle, the greatly increased power losses are only tolerated because of the requirement for the increased traction obtained from a multi-wheel drive with certain vehicles. Even then when more than two wheels are driven it is necessary, with present drives, to cut out all power from the driving wheels which are driven at higher speed because of inter-differential power losses, this condition obtaining in all cases except where three differentials are used in a tandem axle drive. Where three differentials are used many benefits are lost unless at least the inter-axle differential is of a locking type.

So-called fluid drives, as now used in the automotive vehicle drives represent merely fluid clutches and automatic gear shifting devices. Fluid clutches, such as the turbines now used, do not overcome the fundamental defects of a shaft and gear drive and appear to be only stopgap units awaiting the development of compact, positive high pressure, low heat generating fluid drive units. Automatic gear shifting devices in the form of costly and delicate mechanisms have also been added to the present heavy and clumsy substantially full mechanical automotive drives but such gear shifting devices likewise do not overcome the fundamental defects of the present automotive vehicle drives.

Present friction brake mechanisms for automotive vehicles also suffer from inherent defects. Every time a friction brake is applied it wears and has that much less life left in the brake drum and brake lining. While the industry has gone a long way in improving brake drums and brake linings it is believed that the ultimate answer to the braking problem must come through a form of resistance other than through dry friction.

In accordance with the present invention braking is accomplished through the same fluid drive used to propel the automotive vehicle and which is done with oil, a lubricant. In the present fluid drive and braking mechanism no two relatively moving parts ever come in contact with each other because an oil film is always maintained between them. The pressures never build up high enough to destroy the present heavy and clumsy friction brakes.

In the operation of the invention each of the motor and generator units C, D, E, F and G function in the same manner as the wheel motor and generator unit C, illustrated in detail in Figs. 1-5.

In this wheel motor and generator unit C, oil under pressure entering through, say, the boss 63, passes through the arcuate passage 62 and arcuate port 61 into the upper half of the C-shaped working chamber 60, as viewed in Fig. 3, and is increased again by the vanes 33 which divide this upper half of this working chamber into segments and which move radially to maintain contact with the walls of the C-shaped working chamber 60. The pressure of the fluid causes the segmental compartments formed by these vanes 33 to expand in size, thus driving the disk 31 clockwise as viewed in Fig. 3.

When the vanes 33 pass beyond the largest part of the C-shaped working chamber 60 they are forced radially inwardly and the segmental compartments formed thereby are contracted so as to expel the oil from the arcuate port 61, arcuate passage 62 and threaded boss 63. When the oil pressure is reversed, that is, applied from the boss 63, arcuate passage 62 and arcuate port 61, it will be seen that the motor and generator unit C functions in the same manner as above described except that the disk 31 will be rotated in a reverse direction, that is, counterclockwise as viewed in Fig. 3.

This motion of the disk 31 of the motor and generator unit C when so acting as a motor is transmitted through the splines 30 to the hollow shaft 26 which rotates in the roller bearings 22 and 24 and drives the wheel disk 82 and wheel rim 84 fast to the flange 80 of this hollow shaft.

When used as a brake each motor and generator unit C becomes a generator or pump.
torque imposed on the disk 31 from the wheel rim 84, wheel disk 82, hollow shaft 26 and its splines 30 rotates the disk 31 in a corresponding direction relative to the housing 10 and cover plate 13. Since the vanes 33 carried by the disk 31 are biased outwardly, as these vanes travel through the enlarging half of the C-shaped working chamber 65 they form contracting segmental compartments which draw oil from the corresponding arcuate port 61 or 61'. As these vanes travel through the contracting half of the C-shaped working chamber 60 they form contracting segmental compartments to expel oil through the corresponding arcuate port 61 or 61'. Since in braking the flow of oil so pumped in either direction by the wheel motor and generator units C is resisted, a corresponding braking force is imposed on all four wheels of the vehicle.

It is vital that the disk 31 and the vanes 33 fit the side walls 12 and 15 of the circular chamber 15 very accurately. This demand is easily met with the present unit. The open housing 10 can be secured to a machining table. The disk 31 with its vanes can then be placed in the housing, all parts being micro-finished before the cover plate 13 is applied a honing plane can be run over the uncovered assembled unit. This operation will plane all members uniformly to zero tolerances in one operation. The cover plate 13, after having been planed off and polished, can be then applied. The result will be zero tolerances between the disk 31 and vanes 33 and the chamber walls 12 and 15. For clearance a liquid or other type of micro-inch gasket can be incorporated between the face 14 of the housing and the face 13 of the cover plate 13.

This leak tight fit of the disk 31 in its cylindrical chamber 15 is further augmented by the lateral deflickibility of the arcuate, radially outwardly projecting walls 64 defined by the arcuate passages 62, 62', the arcuate ports 61, 61', and the cylindrical chamber. Thus, with a high fluid pressure in either of these passages, the corresponding arcuate wall 64 is deflected laterally to a slight degree to insure a leak tight fit between it and the disk 31, this fit being provided, of course, on the high pressure side of the cylindrical chamber 15 where leakage is most likely to occur.

An important feature in providing immediate reversibility of any unit C, D, E, F or G when acting either as a motor or as a generator resides in the pressures imposed on the inner ends of the vanes 33. The inner end of each vane 33 is in direct communication with the annular channels 45 and 50 in the side rings 45 and 46 secured to the sides of the disk 31. These circular channels in turn communicate with the periphery of the disk 31 through the four radial ducts 52 containing the inwardly opening check valves 56. As a result the pressure at the inner end of each vane 33 is always at least equal to the highest pressure on either side of that vane, because the pressure at the inner ends of the vanes is always equal to the maximum oil pressure in the housing 10. This maximum oil pressure against the inner ends of the vanes 33 insures against the leakage of oil past the outer ends of the vanes at any time. In this connection it will be noted that the face 40 of each shoe 39 is smaller in area than the inner end of its vane 33, leakage past the vanes 33 is further prevented by the form of the shoes 39 at the outer ends of the vanes 33. These shoes present broad faces 40 fitting the peripheral wall 10 of the chamber so that a low unit area pressure obtains with a resulting minimizing of the danger of breaking down the oil film therebetween. At the same time the shoes 39 are free to oscillate in their semi-cylindrical sockets 38 so that the faces 40 always follow the peripheral wall 10 truly. At the same time the lips 42 and pins 44 insure retention of the shoes 39 on the vanes 33 at all times.

In the operation of a motor vehicle equipped with the motor and generator units C, D, E, F and G connected in the manner illustrated diagrammatically in Fig. 1, the driver starts the engine 91, all of the valves 140, 141, 152 and 153 being open. Under this condition the engine is idling and while the shaft 26a and all of the disks 31 with their vanes 33 of the multiple or tandem motor and generator units D—G are rotating the now outlet bosses or outlets 63 of this unit are directly connected to the inlet bosses or inlets 63' of this multiple unit. Thus, the outlet or boss 53 of the unit F is connected through the lines 136, 139, 131 and 135 to boss 63' of this unit F; the outlet boss 63 of the unit D is connected through the lines 144, 145, 131 and 135 to the boss 63' of this unit D; the outlet bosses 63 of the unit E is connected through the lines 148, 151, 131 and 135 to the boss 63' of this unit E; and the outlet boss 63 of the unit G is connected through the lines 154, 155, 131 and 135 to the boss 63' of this unit G. Accordingly, the oil enters each of the units F, D, E and G at substantially the same pressure that it leaves these generators and no power is transmitted to the wheel motor and generator units C. The oil is supplied to the motor and generator units at about 35 pounds pressure from the high pressure side of the system in contrast with the un-stippled lines which represent the return or low pressure side of the system. The pressure building up in the outlet line 136 from the generator F opens the check valve 138 so that pressure flows into the now high pressure side 130 of the system, the other units D, E and G being isolated by the check valves 144, 150 and 155, respectively. The oil from the high pressure side 130 of the system is blocked by the now closed reversing valve 169 and passes through the line 168 past the now open reversing valve 161 into the line 124. The oil flows past the now open braking valve 182 in this line 124 into the line 123 and past the equalizing devices 106 into the lines 104 leading to the now inlet bosses 63 of the wheel units C which now serve as motors. The oil under pressure flowing into the bosses 63 of each wheel motor C flows through the arcuate passage 62 and arcuate port 61 thereof into one end of the C-shaped working chamber 60 so as to drive the disk 31 and its vanes 33 in a clockwise direction as viewed in Fig. 3. As each vane encounters the now outlet arcuate port 61' the arcuate compartment in advance
of this vane starts to contract so that the oil is expelled through the arcuate port 51, arcuate passage 62 and bore 63 into the lines 100 of the lower pressure side of the apparatus. From these lines 100 the returning oil passes through the common lines 101 and 103 past the now open reversing valve 105 into the line 174 and past the now open shut-off valve 172 therein to the reservoir 132 and over the weir or baffle 134 therein to the low pressure side 131 of the system. From the line 131 the oil flows through the corresponding branch 135 into the inlet 63 of the generator unit F to complete the cycle. In passing through the reservoir 132 and over its baffle 134 the oil is cooled, the heat being dissipated through the walk of this reservoir.

In passing through each equalizing device 106 the oil enters from the single inlet line 125 and enters the two working chambers 119 on the corresponding side of the group of four gears 113, these sides of these working chambers being in communication with each other through the opening 126 in the partition 108. Since all of the gears 113 are coupled to rotate in unison through the hexagonal shaft 114, in passing these gears it is apparent that an equal amount of oil is delivered to the outlet side of each chamber 119 regardless of the relative impedance to the flow of oil existing beyond these chambers 119. Accordingly, substantially equal amounts of oil are fed through the two lines 104 to the pair of wheel motors C of each axle regardless of the degree of resistance which each of these wheels offers. Hence each wheel receives power substantially equal to its companion wheel and in proportion to the weight it carries in comparison to the wheels on the other axles. Further, by these equalizing devices 106 power is metered to each wheel in such a way that equal power is applied to both wheels of a given axle when going around corners. To permit the necessary differential movement of the wheels of each axle going around curves, sufficient clearance is left between the gears 113 and casing walls 118 so as to permit the slightly greater flow of oil to one wheel to permit it to travel faster than its companion wheel. However, this slight clearance is not sufficient to permit a substantial differential in the speeds of the wheels but only that necessary to permit the free rounding of curves. Hence, should one wheel be on, say, ice or mud, and the other on dry pavement when the power is applied, the one on ice cannot spin and take power away from the other wheels. Instead, the wheel on the ice will not rotate more than a slight degree faster than the other wheels because the flow of oil to the unrestrained wheel is checked by its equalizing device 106. In effect the equalizing devices 106 are superior to a locking differential because they permit differential action to the required degree but do not allow all the power to go to the wheel which has little traction. A locked differential is bad for steering and tire wear.

As the engine is picked up in speed, an engine speed responsive mechanism (not shown) progressively actuates the rods 159, 153 and 148 to successively open the control valves 155, 152 and 147. This progressively cuts the generator units G, E and D out of operation. Hence beyond the lowest speed the engine to wheel ratio changes are automatic. The engine speed responsive mechanism responds to the engine speed. This has the effect of controlling the engine speed and hence the engine to wheel ratio, if, of course, under control of the driver but the engine to wheel ratio changes automatically without notice or control on the part of the driver. Therefore it is impossible to race the engine because the engine to wheel ratio automatically changes and keeps the engine in the most efficient range at all times.

While the number of motor and generator units as well as the engine to wheel ratio can be widely varied, with a pleasure car, where the road wheel speed does not exceed approximately 1200 K. P. M. at 100 miles per hour, and with the wheel loading uniform and with an engine of a top rating of 3600 R. P. M., a practical application of the invention would call for one motor and generator unit C to drive each wheel and a 3 to 1 gear reduction between the engine 91 and the multiple or tandem generator unit D—G. This multiple or tandem generator unit D—G would contain six generators instead of the four shown to keep within the desirable range of torque and economy without attention from the driver. With such an arrangement the following chart shows a practical range of ratios of engine to wheel speeds and practical engine speeds at which each of the generators is cut into and out of operation:

<table>
<thead>
<tr>
<th>Generator working</th>
<th>M. P. H.</th>
<th>Motor R. P. M.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-10</td>
<td>0-2,000</td>
</tr>
<tr>
<td>2</td>
<td>10-20</td>
<td>1,000-2,000</td>
</tr>
<tr>
<td>3</td>
<td>20-30</td>
<td>1,500-2,500</td>
</tr>
<tr>
<td>4</td>
<td>30-40</td>
<td>2,000-3,000</td>
</tr>
<tr>
<td>5</td>
<td>40-50</td>
<td>2,500-3,500</td>
</tr>
<tr>
<td>6</td>
<td>50-60</td>
<td>3,000-4,000</td>
</tr>
</tbody>
</table>

In commercial applications, the size and number of the fluid drive generator and motor units would be adapted to the particular conditions encountered. For example, in a three axle vehicle where the two rear axles are used it is practical to use the same size of motor and generator units C on the two rear axles as are used in the tandem or multiple unit D—G connected with the engine. However, in this vehicle the front axle, if designed to carry a lighter load, would be powered by front axle motor and generator units C identical to those used on the rear axles except for the depth of the cylindrical chamber 15 which would be designed to have only a proportional capacity of the rear or heavier axle units C.

It will be seen that the invention is completely flexible for application to all types of vehicles and engines and is adaptable to highway pleasure cars, buses, trucks, trailers and railroad cars.

When the driver wishes to brake the vehicle all that is necessary is to actuate the brake valve lever (not shown) to actuate the rod 180 and turn the brake valves 160, 162 toward their closed position. The extent to which these brake valves are closed will determine the degree of braking of the vehicle. When the vehicle is moving the brake valves serve as providing the brake valves are ineffective as the oil is free to bypass through the bypass 188 past the check valve 189 therein and which opens toward the line 133. However, with
such forward movement of the vehicle the brake valve 180 is effective since the check valve 186 in its bypass 185 is closed against oil flow in the corresponding direction. Closing this brake valve 186 restricts the flow of oil from the wheel motor and generator units C (assuming forward movement of the vehicle) since it is assumed that the driver would release the accelerator in braking, this restriction also restricts the direct return of oil to the wheel units C through the open lines 156, 151 or 145. With such braking the wheel motor and generator C instantaneously becomes a motor or pump, pumping the oil in the same direction as before but reversing the relation between the high and low pressure sides of the system as distinguished by the stippled and un-stippled parts of the system in Fig. 1. The flow of oil from the now high pressure to the low pressure side of the system is resisted by the brake valve 180 which is now on the high pressure side of the system and hence the vehicle is decelerated to the degree desired.

When the driver wishes to reverse the vehicle all that is necessary is to actuate a small manual or foot lever (not shown) to actuate the rod 176 and turn the reversing valves 161, 166 into the opposite relation shown in Fig. 1, that is, to close the valve 161 and open the valve 166. At the same time, through the centrally pivoted lever 178, this movement of the rod 176 opens the shut-off valve 165 so as to render the line 164 operative and closes the shut-off valve 172 to render the line 174 inoperative. With this reversing of these four valves the flow of high pressure oil from the side 130 is through the line 166 and past the manually open reversing valve 166 and hence through the line 103 with its open brake valve 180 and bypass 185 to the lines 101 and 100 leading to the bosses 63 of the wheel motor and generator units C, the flow of fluid to the side 131 being blocked off by the now closed shut-off valve 172. It will therefore be seen that the high pressure side of the system is now the un-stippled portion thereof as viewed in Fig. 1, this being the reverse of the condition which obtains during forward driving of the vehicle. After passing in a reverse direction through the several wheel motor and generator units C, the oil flows into the lines 104 and through the equalizing devices 106 to the line 123. From this line 123 the oil flows through the line 124 and its open brake valve 182 into the line 164 and past the new open shut-off valve 165. From the line 164 the oil flows into the side 131 of the line and into the branches 135 leading to the inlets 63 of the multiple or tandem generators D—G. This completes the circuit of the oil flow in driving the vehicle in a reverse direction. It will be noted that in this reversing of the vehicle the oil, in effect, is by-passed around the reservoir 132 in that it does not pass over the baffles 134 therein. The cooling effect provided by this reservoir 132 is not required with low reverse speeds of the vehicle and by this expedient of, in effect, by-passing this reservoir in reversing, this influence is eliminated.

In decelerating the vehicle while traveling in a reverse direction, the operator moves the brake rod 183 to close the brake valves 180, 182 the desired degree in the same manner as when going forwardly. With the reverse flow of oil through the system when the vehicle is traveling in reverse the brake valve 180 is ineffective since the check valve 186 in its bypass line opens in the reverse direction of oil flow as above described. However, the check valve 186 in the bypass 185 associated with the brake valve 182 closes in this reverse direction of oil flow and hence renders the brake valve 182 effective to restrict the flow of oil through the wheel units C. Since in braking the operator would release the accelerator and hence open the line through the multiple or tandem motor and generator unit D—G and since in braking each wheel motor and generator unit C becomes a generator or pump, the restriction offered by the brake valve 182, in reverse movement of the vehicle, operates to check the movement of all wheels of the vehicle to any desired degree. Further, since when the wheel motor and generator units C so become generators, the high and low pressure sides of the system reverse, it will be seen that the brake valve 182 is in the high pressure side of the system when decelerating the vehicle traveling in reverse. Thus, decelerating in forward travel the operative brake valve 182 is in the then high pressure side of the system and when decelerating in reverse travel the operative brake valve 182 is in the then high pressure side of the system, thereby to obtain uniformity in braking under all conditions. This is accomplished by the check valve bypasses 185 and 186.

In decelerating or braking the vehicle while traveling in either direction by so closing the brake valves 180, 182, the heat generated is dissipated in the reservoir 132 which serves as a combination reservoir and radiator. The braking effect can be applied for several miles or a few feet without causing any added wear to the parts. The energy is not absorbed by friction but is resisted by restriction to the oil flow and turned into heat. The radiating effect of the reservoir 132 is ample to take care of continuous brake applications regardless of how long or severe the application. No wear occurs in the system while braking because all moving parts are surrounded by an oil film and the pressure between the parts are never high enough to break the oil film. For example, the vehicle could be driven for thousands of miles with a continuous brake application and no more wear would show up in the driving or braking portions of the system than if no brakes had been applied. The only bad effect would be found in the engine because of the continuous heavy load applied to it.

It will also be seen that the driver can use the engine as a brake. Thus, when the throttle for the engine 91 is closed with the vehicle moving, the movement of the vehicle turns the wheels at a speed in excess of the oil supplied to the wheel motor and generator units C so that these wheel motor and generator units C instantly become generators and pump the oil through the multiple or tandem motor generator D—G. This multiple or tandem generator unit therefore becomes a motor and turns the engine 91. The engine, as in a conventional vehicle, without free wheeling, resists the vehicle movement. This resistance will not create any more heat in the fluid system than the driving effect does.

It will further be seen that at low speeds the oil in the system will travel quite slowly and at its highest pressure, thereby providing the necessary power to provide a heavy pulling effect upon the vehicle. The entire capacity of the engine 91 is applied to the single generator F when so traveling at low speed and where heavy pulling of the vehicle is encountered. As the vehicle speed increases and additional generators D, E and G come into action, the fluid pressure is reduced. However, at higher engine speeds a larger volume
of oil is pumped and the oil travels at a progressively higher speed or velocity but at a lower pressure.

It will be seen that each of the wheel motor and generator units as shown in detail in Figs. 2-5 is adequately sealed against the loss of oil, particularly against the loss of oil under high pressure. Thus, the reservoir pressure of, say 25 pounds, will obtain throughout the entire unit up to the oil seals 25 and 19 at the outer end of the hollow shaft 26. Whatever high pressure fluid passes between the disk 31 and the walls 12 and 16 of its circular chamber 15 automatically passes to the low-pressure zone of the unit. Therefore, there will be no fluid loss except that which passes the seals 25 and 19 under the minimum pressure in the system. Accordingly, the units will lose very little oil and the amount of fluid required to replenish the system through loss of operation is negligible.

From the foregoing it will be seen that the present invention provides an extremely simple, efficient and compact fluid drive and brake mechanism, particularly for automotive vehicles, which overcomes the many inherent defects of present mechanical and semi-mechanical drive and braking systems and accomplishes the various objects set forth.

I claim:

1. A fluid drive unit comprising a housing providing a cylindrical chamber, a piece cylindrical disk journaled eccentrically in said chamber and having opposite planar side walls fitting the side walls of said cylindrical chamber, said disk being provided with a plurality of spaced slots extending generally radially inwardly from its periphery, part way into the disk and having closed bottoms, a vane fitted in each of said slots for radial movement relative to said disk and fitting said side walls of said cylindrical chamber, a ring separate from said disk arranged in an annular chamber provided in said housing concentric with the axis of said disk and adjacent the inner ends of said slots, means securing said ring to one side wall of said disk said ring being provided on its disk side with an annular channel registering with the inner end of each of said slots, means for admitting and relieving fluid to and from the space in said cylindrical chamber between the periphery of said disk and the opposing wall of said housing in driving relation to said vanes, and a plurality of check valves each arranged in a passage through said disk leading from said space to said annular channel and opening toward said channel to transmit substantially the highest fluid pressure developed in said housing from said space to said annular channel.

2. In a fluid drive unit having a housing providing a cylindrical chamber, a cylindrical disk journaled eccentrically in said casing and having opposite planar side walls fitting the side walls of said cylindrical chamber, said disk being provided with a plurality of spaced slots extending generally radially inwardly from its periphery, a vane fitted in each of said slots for radial movement relative to said disk and fitting said side walls of said cylindrical chamber, means biasing said vanes radially outwardly into contact with the peripheral wall of said cylindrical chamber, the combination therewith of means for admitting and relieving fluid to and from said cylindrical chamber in driving relation with said vanes, comprising an elongated arcuate port in said side wall of said cylindrical chamber and communicating with one end of the enlarging space between said eccentric disk and said cylindrical chamber for a substantial distance along the length of said space, said housing being provided with a second elongated arcuate port in said side wall of said cylindrical chamber and communicating with the other end of the space between said eccentric disk and said cylindrical chamber for a substantial distance along the length of said space, and said housing being provided with an arcuate passage conforming and communicating with each of said arcuate ports on the side thereof remote from said cylindrical chamber and said arcuate passages being disposed radially inwardly from said arcuate ports to provide radially outwardly projecting walls of a thickness permitting said walls to be deflected laterally into sealed engagement with said disk by high fluid pressure in said arcuate passages, and means connecting said arcuate passages to opposite sides of the fluid lines serving the units.

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References Cited in the file of this patent

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>146,010</td>
<td>Manley</td>
<td>Dec. 30, 1873</td>
</tr>
<tr>
<td>603,972</td>
<td>Loflin</td>
<td>Dec. 16, 1900</td>
</tr>
<tr>
<td>788,035</td>
<td>Fergusson</td>
<td>Apr. 25, 1905</td>
</tr>
<tr>
<td>861,117</td>
<td>Muller</td>
<td>Sept. 3, 1907</td>
</tr>
<tr>
<td>1,164,097</td>
<td>Wallsted</td>
<td>Dec. 21, 1918</td>
</tr>
<tr>
<td>1,287,776</td>
<td>Allan</td>
<td>Feb. 26, 1918</td>
</tr>
<tr>
<td>1,298,178</td>
<td>Churchill</td>
<td>Mar. 25, 1919</td>
</tr>
<tr>
<td>1,787,965</td>
<td>Brown</td>
<td>Jan. 6, 1931</td>
</tr>
<tr>
<td>1,798,738</td>
<td>Hoern</td>
<td>Mar. 31, 1931</td>
</tr>
<tr>
<td>1,928,623</td>
<td>Turek</td>
<td>Sept. 12, 1923</td>
</tr>
<tr>
<td>2,243,404</td>
<td>Kuecher</td>
<td>May 27, 1941</td>
</tr>
<tr>
<td>2,255,782</td>
<td>Kendrick</td>
<td>Sept. 16, 1941</td>
</tr>
<tr>
<td>2,357,333</td>
<td>Kendrick et al.</td>
<td>Sept. 5, 1944</td>
</tr>
<tr>
<td>2,474,348</td>
<td>Czernick</td>
<td>June 28, 1949</td>
</tr>
</tbody>
</table>