

Nov. 29, 1966

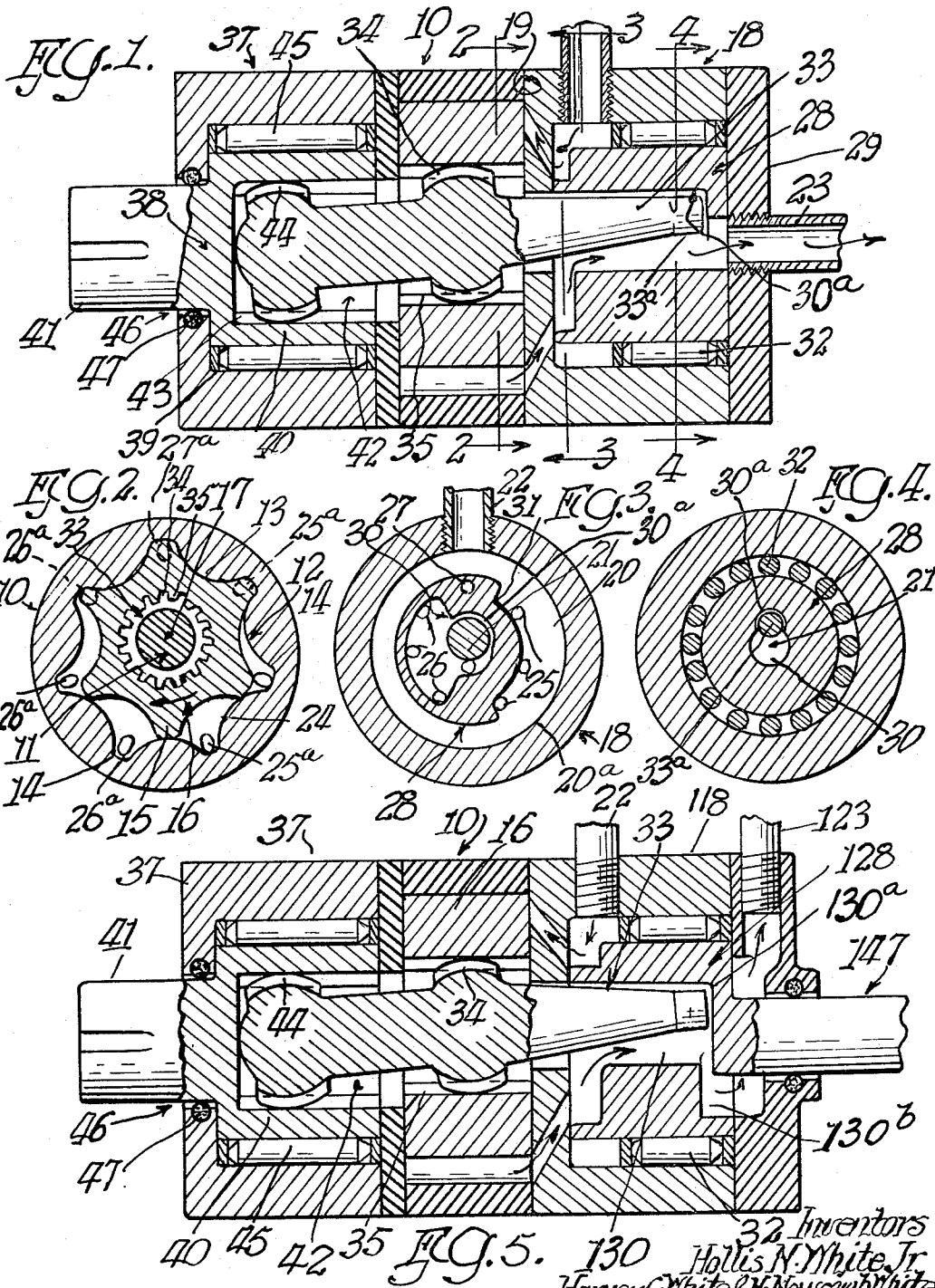
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3,288,034

ROTARY MOTOR OR PUMP

Filed Feb. 24, 1965

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

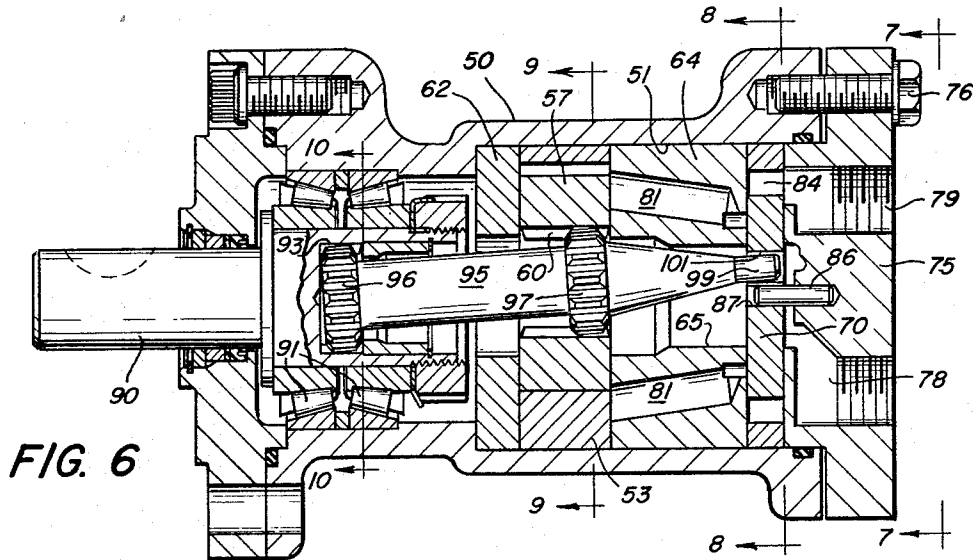


FIG. 6

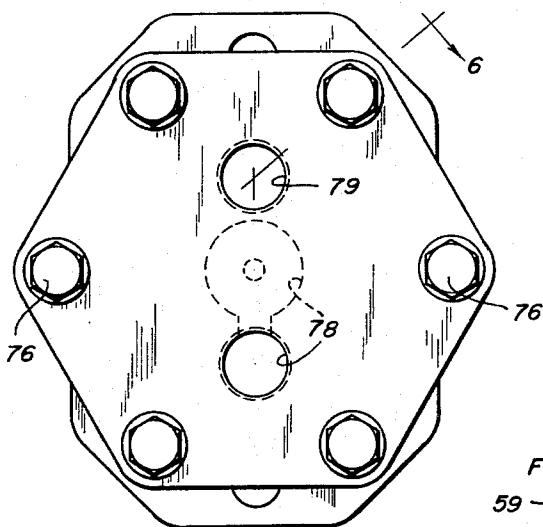


FIG. 7

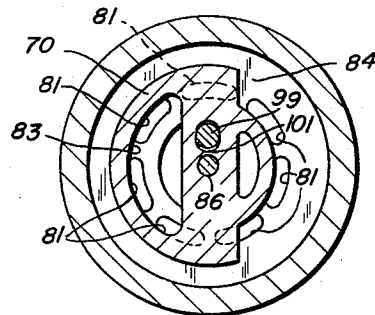


FIG. 8

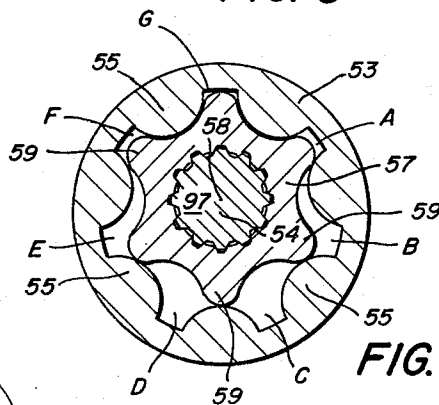


FIG. 9

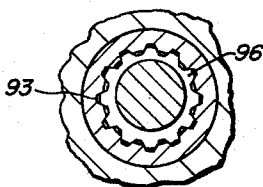


FIG. 10

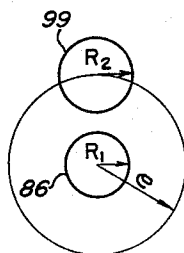


FIG. 11

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1

3,288,034

ROTARY MOTOR OR PUMP

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Filed Feb. 24, 1965, Ser. No. 439,511

15 Claims. (Cl. 91—56)

This application is a continuation-in-part application of United States Serial Number 304,942 filed August 27, 1963 for Hydraulic Motor.

This invention relates to a hydraulic pump or motor, and, more particularly, to a hydraulic pump or motor wherein the rotor portion has a hypocycloidal movement.

Although hydraulic devices of the type with which the invention is concerned have been known for a long time—the idea of having an externally toothed rotor with less gear teeth than the internally toothed stator—there has been a problem in providing means for satisfactorily driving the rotor in the case of a motor or for introducing and exiting fluid in the case of a pump. The previous expedients have inclined complicated valving systems, and even where the valving system has been of the commutator type, it has been too complex to provide reliable operation.

It is, therefore, an object of the invention to provide a hydraulic pump or motor of the hypocycloidal type which avoids the problems of the prior art, and, more particularly, provides a novel and reliable means for commutating the pressure fluid employed by the pump or motor.

Another object of the present invention is to provide in a hydraulic device of the internal external gear type wherein one of the members rotates and orbits relative to the other, the provision of driving a commutator by means of an eccentric pin type connection between the orbiting member and commutator whereby the commutator is driven only in accordance with the orbital movement of the moving member.

Another object of the present invention is to provide in a hydraulic device of the internal external gear type wherein one of the members rotates and orbits relative to the other, the novel mounting of a commutator and eccentric drive therefor from the movable member wherein the drive functions efficiently and does not become an eccentric lock as in prior art devices.

Another object of the present invention is to provide in a hydraulic device of the internal external gear type wherein one of the members rotates and orbits relative to the other, an operating member connecting a shaft and the movable member by means of universal joint type connections and an extension of the operating member serves as an eccentric drive member to rotate a commutator in accordance with the orbiting of the movable member.

Another object of the present invention is to provide in a hydraulic device of the internal external gear type wherein one of the members rotates and orbits relative to the other and a commutator regulates flow of fluid to and from the device, the provision of connection means between these recited elements and a shaft wherein only torque and no radial or axial loads are transmitted therebetween.

Another object of the present invention is to provide in a hydraulic device of the internal external gear type wherein one of the members rotates and orbits relative to the other, the provisions of a commutator which is of a face type valving design as distinguished from a peripheral type and the fluid ports and passages in the device provide for a generally straight through and unobstructed flow of fluid to and from the internal external gear portion of the device.

2

Other objects and advantages of the invention may be seen in the details of construction and operation set down in this specification.

The invention is explained in conjunction with an illustrative embodiment in the accompanying drawing, in which:

FIGURE 1 is an elevational view, partially in section, of the invention described as a motor;

FIGURES 2, 3 and 4 are sectional views taken along the lines 2—2, 3—3 and 4—4, respectively, as applied to FIGURE 1;

FIGURE 5 is an elevational view, partially in section, of a modified form of the invention;

FIGURE 6 is an elevational view, partially in section, of a modified form of the invention;

FIGURE 7 is a view taken generally along the line 7—7 of FIGURE 6;

FIGURE 8 is a view taken generally along the line 8—8 of FIGURE 6;

FIGURE 9 is a view taken generally along the line 9—9 of FIGURE 6;

FIGURE 10 is a view taken generally along the line 10—10 of FIGURE 6; and

FIGURE 11 is a schematic view showing the path of movement of two of the elements of the device shown in FIGURES 6 through 10.

In the illustration given, and with particular reference to FIGURE 1, the numeral 10 designates generally a first casing, which is seen to be generally cylindrical. The casing 10, as represented in FIGURE 2, has an axis 11 and an interior wall generally designated 12. The interior wall 12 is equipped with a plurality of teeth or high points 13, suitably spaced apart to define a similar number of low points 14. For the sake of brevity, the high points 13 are referred to as gear teeth, and it will be seen from a consideration of FIGURE 2 that these are adapted to cooperate in the usual fashion with the external teeth 15 of a rotor generally designated 16.

The rotor has one less tooth 15 than the number of teeth 13, and, in the illustration given, the rotor 16 has six teeth 15, while the stator portion defined by the first casing 10 has seven teeth 13. The axis 17 of the rotor 16 is seen to be offset from the axis 11 of the casing 10, so that the movement developed by the rotor 16 is hypocycloidal, i.e., possessing both rotary and orbital components.

For the purpose of developing the above-mentioned hypocycloidal movement in the rotor 16, a second casing generally designated 18 is provided. The second casing 18 is suitably secured by bolts (not shown) to a first outer face 19 of the first casing 10. Like the first casing 10, the second casing 18 is cylindrical and, as seen in FIGURE 3, is equipped with an axially-extending chamber 20 which has an axis 21 coaxial with the axis 11 of the first casing 10. Pressure fluid is introduced into the chamber 20 through a radially-extending flow or inlet port 22 and pressure fluid is removed from the second casing 18 through a generally axially-extending flow or outlet port 23.

The pressure fluid entering the inlet flow port or passage 22 reaches the stator chamber 24 by means of flow passages or ports 25. Pressure fluid exiting from the stator chamber 24 reaches the outlet passage 23 through other flow passages or ports 26. Thus, at any given instant, in the illustration given, there is one flow passage or port 27 (see FIGURE 3) which is neither supplying nor removing pressure fluid from the stator chamber 24.

The commutation of the passages 25—27 is achieved by a commutator generally designated 28 and which is seen in FIGURES 1, 3 and 4. An endplate 29 may be employed to confine the commutator 28. The commutator 28 is generally cylindrical in nature and has an axis

3

coincident with the axis 21 and coaxial with the axis 11. The commutator 28 is equipped with a generally axially-extending bore 30 which, in FIGURE 3, is seen to be in communication with the passages 26. The commutator 28 is also equipped with a peripheral notched portion 31 which, also in FIGURE 3, exposes the passages 25. Thus, in the condition shown, pressure fluid is entering the ports 25a as designated in FIGURE 2, while the spent fluid in exiting from the stator chamber 24 through ports 26a, the port 27a being blank. This causes the rotor 16 to rotate in the direction indicated by the arrow applied thereto in FIGURE 2, with the consequent change in character of the various ports. Thus, at any given time, there are a plurality of ports 26a, (less than the total number of passages 25-27) which are communicated with the outlet passage 23 and a similar plurality of ports 25a, mutually exclusive from the first-mentioned plurality, in communication with the inlet passage 22.

The commutator 28 is advantageously supported for rotation within the chamber 20 by means of needle roller bearings 32, and it is seen that the passages 25-27 are arranged to communicate with the chamber 20 a spaced distance inward of the chamber-defining wall 20a. In the illustration given, this is achieved through inclining axially inwardly the passages 25-27, as best seen in FIGURE 1.

The rotation of the commutator 28 is achieved through an amplification pin generally designated 33 and which is seen to extend into a portion of the bore 30, the portion in which the pin 33 is received being designated 30a and which is seen to be eccentric to the axis 21. The pin 33 has an intermediate splined portion 34 cooperating with a splined bore 35 provided in the rotor 16, the splined bore 35 being concentrically related to the axis 17 of the rotor 16. Thus, as the rotor 16 follows its hypocycloidal path within the stator chamber 24, the amplification pin 33 loses the rotational component of the hypocycloidal movement, but amplifies the orbital component to drive the commutator 28.

The left-hand side (as illustrated) of the casing 10 has secured thereto a third casing generally designated 37. The third casing 37 has an axis 38 coaxial with the axes 11 and 21, and provides a chamber 39 in which an annularly enlarged portion 40 of an output shaft 41 is housed. The annularly enlarged portion 40 has an axial bore 42 splined as at 43 for cooperation with the splined portion 44 provided on the end of the amplification pin 33 opposite the end received in the commutator 28. The annularly enlarged portion 40 is suitably journaled within the chamber 39 by means of needle bearings 45, and the shaft 41 extends out of an end opening 46 which is suitably sealed by means of an O-ring 47. Thus, the shaft 41 rotates, in the illustration given, at a speed one-sixth as fast as that of the commutator 28 and in the opposite direction. The output shaft thus utilizes only the rotational component of the rotor 16, ignoring the orbital component.

In summary, the operation of the hydraulic motor utilizes each orbit of the rotor 16 to drive the commutator 28 one revolution. Each sixth turn or orbit of the rotor 16 drives the output shaft one revolution and in a direction opposite to that of the commutator. At the other side of the rotor 16, the orbiting component of the hypocycloidal movement is utilized to drive the commutator 28. The rotational component of the hypocycloidal movement of the rotor 16 is lost because the amplification pin has a universal-acting cylindrical end portion 33a engaging the eccentric portion 30a of the bore 30 of the commutator 28. However, the amplification pin 33 does pick up the orbital component of the hypocycloidal movement of the rotor 16, and this is amplified by the length of the pin 33 and the angle which it forms with the axis 11.

In FIGURE 5, an arrangement essentially similar to that of FIGURE 1 is seen, wherein the output shaft is again designated 41, the third casing generally designated 7, the first casing generally designated 10, and the sec-

4

ond casing generally designated 118. Again, there is an amplification pin generally designated 33 and a commutator in FIGURE 5 generally designated by the numeral 128. The rotor again is generally designated 16. The commutator 128 is equipped with an integral, axially-extending output shaft generally designated 147, and this provides a high speed output, in the illustration given, six times as fast and in the opposite direction from the output shaft 41. Since the output shaft is on the axis of the commutator 128, a different output passage arrangement is required, and it is seen in FIGURE 5 that the output passage for the pressure fluid extends radially as at 123, the bore 130 of the commutator being annularly enlarged as at 130b for this purpose, as well as having the eccentric portion 130a for the receipt of the amplification pin 33.

The pin 33, if desired, may take the direct orbit of the rotor 16 as by being arranged at a zero angle to the axis 21, thereby eliminating any amplification.

FIGURES 6 through 11 illustrate a still further modification of the invention disclosed herein and this particular embodiment of the invention will be more specifically described as a pump. It will be readily appreciated by those skilled in the art that the teachings of the present invention are as readily adaptable to a pump as to a motor. The particular hydraulic device described at this point, namely a pump, includes in combination a casing 50 having wall means which define a bore 51. An internally toothed stator 53 is fixedly secured or mounted in the casing bore and has an axis 54 which is coaxial with the casing axis. Mounted within the stator is an externally toothed rotor 57 which has an axis 58 and one less tooth than the stator 53 and this rotor is adapted to undertake rotational movement and also orbital movement whereby its axis 58 orbits with respect to the axis 54 of the stator. The rotor and stator may be referred to as fluid displacement means. This movement is generally referred to as hypocycloidal movement. The teeth on the stator have been identified by the reference numeral 55 and the teeth on the rotor have been identified by the reference numeral 59. Wall means serve to define a splined bore 60 which extends through the central portion of the rotor and coaxial therewith. Movement of the rotor 57 through the above mentioned rotational and orbital movement relative to the stator creates a plurality of alternately expanding and contracting chambers between the rotor and stator teeth or more specifically the chambers are located between the stator teeth and the expanding and contracting is caused by the movement of the rotor teeth into and out of these spaces. These chambers have been identified by the reference letters A, B, C, D, E, F and G.

A closure plate 62 is positioned in the casing bore 51 on the left side of the rotor and stator construction as seen in FIGURE 6 and provides a closure for the above referred to chambers on this side of the rotor and stator. A cylindrical porting member 64 is positioned in the casing bore on the other side of the rotor and stator and is provided with wall means which define a bore 65 which extends generally axially therethrough and a first face is located flush with an end face on the rotor and stator. A second face of the porting member is positioned adjacent and flush with the first face of a generally cylindrically or annular shaped commutator 70 which is mounted in the casing bore for rotatable movement above an axis coaxial with the stator axis 54. A second face of the commutator 70 is located adjacent an inside wall surface of an end plate 75 held in place by bolts 76 which serve to close an end of the casing 50. As seen, the end plate 75 is provided with inlet and outlet ports 78 and 79 respectively which extend in a generally axial direction.

The porting member 64 is provided with a plurality of circumferentially spaced ports 81, totaling in this embodiment seven in number. The left end of these ports communicate respectively with the chambers A through G

5

and then extend in a generally axial direction to the second face of the porting member. The commutator member is provided with wall means which define input and output passages 83 and 84 so named in this particular instance because of the hereinafter described direction of rotation of the device, it being clearly understood by those skilled in the art that when the direction of rotation is reversed, the function of the input and output passages is likewise reversed. These input and output passages also extend in generally an axial direction and it will be noted from viewing FIGURE 8 that each of these passages has a sufficient circumferential and radial extent to encompass or cover more than one of the circumferentially spaced ports 81 at any given time. It will be seen in FIGURE 8 that the output passage 84 is in fluid communication with three of the ports 81 and the input passage 83 is in communication with three of the ports.

The commutator which is of the face type as distinguished from the peripheral type, is mounted for rotation by means of a pin member 86 which is fixedly secured to the end plate 75 at its right end as seen in FIGURE 6 and has its left end received within an opening 87 in the commutator 70. The pin member 86 and the opening 87 are located on the axis of the casing and coaxial with the stator axis 54.

An input or output shaft 90 which may be referred to in the case of a pump as a drive shaft and in the case of a motor as a driven shaft, is suitably mounted for rotation upon bearings 91 within the casing 50 and has an axis of rotation coaxial with the stator axis. The shaft 90 has a splined recess 93 within its end which resides within the casing and as will be noted the other end extends to the exterior of the casing. An operating or amplifying member 95 is located within the casing and has a splined or toothed portion 96 referred to at times as a third point or portion which functions as a fulcrum and which resides within the splined recess 93 of the shaft 90. The operating member is also provided with a splined or toothed portion 97 referred to at times as a first point or portion which resides within the splined bore 60 of the rotor and this member also extends through the axial opening in the closure plate 62. The connection of the rotor 57 to the shaft 90 by means of the operating member 95 serves to transmit rotative movement between the shaft 90 and the rotor 57 while in effect filtering out the orbital component of the rotor, particularly in the case where the rotor is driving the shaft in the case of a motor. In the case of a pump, while the shaft is rotating the rotor, the rotor is also undergoing orbital movement. The connecting of the operating member by means of the splined portions 96 and 97 provides in effect a universal joint at each of these positions. The operating member functions as a wobble stick.

The operating member is provided with an extension 99 referred to at times as a second point or portion which extends as a continuation of the operating member beyond the rotor and resides on the axis of the operating member and as will be noted, is displaced from the axis of the stator or casing a distance greater than the rotor axis 58 is displaced from the stator axis. As will be described hereinafter, this extension provides an eccentric drive with respect to the stator axis and this extension serves to amplify this eccentric drive at least with respect to a corresponding portion of the extension at the place where it leaves the rotor.

Wall means are provided in the commutator member and define a drive opening 101 within which the end of the extension 99 resides and this connection or eccentric drive serves to rotate the commutator in accordance with the orbital movement of the rotor. In other words, as the rotor axis orbits the stator axis, the extension 99 must also orbit the stator axis and in going through this movement causes the commutator to rotate about the pin member 86 which rotatively mounts the same. The extension also rotates in accordance with the rotation of the rotor,

6

however, the extension merely turns relative to the drive opening 101 since there is no engagement to transmit the rotative movement of the rotor and in effect the rotative movement is rendered ineffective or filtered out.

In the use of the means which have been just described hereinabove, for driving the commutator, which means may be referred to as an eccentric drive, it is important that the drive, to be functionally effective, does not result in an eccentric lock. This may be explained in the present embodiment by the following explanation taken in conjunction with FIGURE 11. FIGURE 11 is a schematic view (enlarged three times) illustrating the pin member 86 mounting the commutator for rotation along with the extension 99 driving the commutator and showing the extension 99 eccentric throw (e) with respect to the stator axis 54 about which it turns. In order that the drive be effective, it is important that the following equation hold true, namely that:

$$\frac{k_1 R_1}{k_2} + R_2 < \frac{e}{k_2}$$

wherein R_1 equals the radius of the means (86) rotatably mounting the commutator, R_2 equals the radius of the driving means (99), k_1 equals the coefficient of friction for R_1 , k_2 equals the coefficient of friction for R_2 , and e equals the eccentric throw. Analyzing the device shown in FIGURES 6 through 11 and scaling a device proportionally the same size as shown in these drawings indicated that R_1 (86) equals .093 inch, R_2 (99) equals .109 inch, e equals .250 inch. A conservative coefficient of friction of .18 was assumed for the friction of response for lubricated metal to metal contact. Since in this case k_1 the coefficient of friction for the contact between the pin member 86 and the opening within which it resides 87 and the coefficient of friction k_2 for the contact between the extension 99 and the opening 101 within which it resides are the same, it can be said that $k_1 = k_2$. As a result, the formula from above becomes:

$$R_1 + R_2 < \frac{e}{k}$$

As a result, utilizing the numerical values given above, the calculations are as follows:

$$.093 + .109 < \frac{.250}{.18}$$

$$.202 < 1.39$$

This establishes that an eccentric lock does not result and also shows that the orbital eccentric drive of this particular design works by a factor of:

$$\frac{1.39}{.202} = 6.88$$

For the sake of example, in calculating a corresponding design utilizing roller type bearings instead of the metal to metal contact herein defined, one may assume a conservative coefficient of friction of .01.

The operation of the device as a pump and viewing the device in the direction of FIGURES 8 and 9 will be described as follows. With the shaft 90 driven in a counter-clockwise direction, the rotor 57 will likewise be caused to rotate in a counter-clockwise direction about its own axis 58, however, the rotor axis 58 will move about, or orbit, the stator axis 54 in a clockwise direction which will cause the chambers A, B and C (in the position shown in FIGURE 9) to be on a pressure stroke and chambers

D, E, and F being on an intake stroke with chamber G being at a transition point. One rotation of the shaft 90 will cause the rotor 57 to rotate one complete revolution about its own axis and cause its axis 58 to orbit the stator axis 54 six times. The operating member 95 including portions 96 and 97 may be referred to as an intermediate shaft and its axis in transmitting movement between shaft 90 and the rotor 57 describes generally the surface of a cone. The chambers A, B, and C are placed in communication with the output passage 84 by means of the ports 81 which are aligned with this part of the commutator (see FIGURE 8) and the input passage 83 of the commutator provides fluid to the chambers D, E, and F by means of the ports 81 which are in communication therewith. As seen in the drawings, the input passage 83 is at all times in communication with the inlet port 78 and the output passage 84 is at all times in communication with the outlet port 79. The commutator makes one complete rotation upon one complete orbit of the rotor because of the driving connection by means of the extension 99 and drive opening 101 and as a result the chambers which are contracting are always connected to the outlet port 79 and the expanding chambers are always connected to the inlet port 78.

It will also be readily apparent to those skilled in the art that the principles disclosed herein are also readily adaptable to a construction wherein the alternately contracting and expanding chambers result in a construction wherein the inner member referred to as the rotor in this particular embodiment is held in a fixed position and the outer member which has been referred to as the stator is caused to rotate and orbit with respect to the inner member.

As a result of the above construction, it will be readily apparent that a new and effective means of driving a commutator from the movement of an internal external gear type of hydraulic device is provided which also admits of a convenient and efficient type of commutator construction. There has also been demonstrated an efficient and novel means of rotatively mounting the commutator when an eccentric driving means is utilized to rotate the same. It has also been illustrated in the present invention that the rotative component of an internal external gear set can be communicated to a shaft whereas the orbital component of the gear set can be used to drive a commutator. The present construction also illustrates a construction where there are no radial or axial loads imposed upon the internal external gear set or the commutator, from the shaft, and the design also provides a substantially straight through flow to and from the external internal gear set.

While in the foregoing specification a detailed description of an embodiment of the invention has been set down for the purpose of illustration, many variations in the details herein given may be made by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A hydraulic device comprising an internally toothed fixedly mounted stator, an externally toothed rotor mounted within said stator and having a lesser number of teeth than said stator, said rotor being capable of rotary movement about its own axis and orbital movement about the stator axis, said rotary and orbital movement of said rotor creating a plurality of alternately expanding and contracting chambers between the teeth on said rotor and on said stator, a movable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, a main shaft rotatably mounted in a position coaxial with said stator, an intermediate shaft having first and second portions, means connecting said first portion of said intermediate shaft to said main shaft and said second portion of said intermediate shaft to said rotor whereby said main shaft and said rotor rotate together and the axis of said intermediate shaft describes

generally the surface of a cone upon movement thereof, and means coupling said rotor and commutator together for moving said commutator only in response to the orbital movement of said rotor.

2. A hydraulic device comprising a casing, an internally toothed stator fixedly mounted with said casing, an externally toothed rotor mounted within said stator and having a lesser number of teeth than said stator, said rotor being capable of rotary movement about its own axis and orbital movement about the stator axis, said rotary and orbital movement of said rotor creating a plurality of alternately expanding and contracting chambers between the teeth on said rotor and on said stator, a rotatable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, a pivot member extending between said commutator and said casing and coaxial with said stator for rotatably mounting said commutator, a shaft coupled to said rotor and responsive only to the rotary movement of said rotor, and a pin member connected to said rotor for travel therewith in its orbital movement thereby describing an eccentric path with respect to the stator axis, wall means on said commutator, said pin member engaging said wall means on said commutator for rotating said commutator once for each orbit of said rotor.

3. A hydraulic device comprising a casing, an internally toothed stator fixedly mounted within said casing, an externally toothed rotor mounted within said stator and having a lesser number of teeth than said stator, said rotor being capable of rotary movement about its own axis and orbital movement about the stator axis, said rotary and orbital movement of said rotor creating a plurality of alternately expanding and contracting chambers between the teeth on said rotor and on said stator, a rotatable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, a pivot member extending between said commutator and said casing and coaxial with said stator for rotatably mounting said commutator, a shaft coupled to said rotor and responsive only to the rotary movement of said rotor, and a pin member connected to said rotor for travel therewith in its orbital movement thereby describing an eccentric path with respect to the stator axis, wall means on said commutator, said pin member engaging said wall means on said commutator for rotating said commutator once for each orbit of said rotor, the following equation holding true for said hydraulic device, namely:

$$R_2 + \frac{k_1 R_1}{k_2} < \frac{e}{k_2}$$

wherein,

R_2 = radius of said pin member

R_1 = radius of said pivot member

k_2 = coefficient of friction for pin member and wall means on commutator engagement

k_1 = coefficient of friction for pivot member rotatably mounting commutator

e = distance between pin member axis and pivot member axis.

4. A hydraulic device comprising a casing, an internally toothed stator fixedly mounted within said casing, an externally toothed rotor mounted within said stator and having a lesser number of teeth than said stator, said rotor being capable of rotary movement about its own axis and orbital movement about the stator axis, said rotary and orbital movement of said rotor creating a plurality of alternately expanding and contracting chambers between the teeth on said rotor and on said stator, a rotatable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, a

shaft coaxial with said stator, an operating member having first and second portions, said first portion of said operating member being connected to said shaft by a universal joint connection and said second portion of said operating member being connected to said rotor by a universal joint connection, said operating member having an axis which extends at an angle to the stator axis, said operating member having an extension which cooperates with said commutator for rotating said commutator once for each orbit of said rotor, said shaft and rotor being rotatable together.

5. A hydraulic device comprising a casing, an internally toothed stator fixedly mounted within said casing, an externally toothed rotor mounted within said stator and having a lesser number of teeth than said stator, said rotor being capable of rotary movement about its own axis and orbital movement about the stator axis, said rotary and orbital movement of said rotor creating a plurality of alternately expanding and contracting chambers between the teeth on said rotor and on said stator, a rotatable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, a pivot member rotatably mounting said commutator and being coaxial with said stator, a shaft coaxial with said stator, an operating member having first and second portions, said first portion of said operating member being connected to said shaft by a universal joint connection and said second portion being connected to said rotor by a universal joint connection, said operating member having an axis which extends at an angle to the stator axis, said operating member having an extension which lies on the operating member axis and which is displaced from the stator axis a greater distance than a corresponding portion of said operating member at said rotor, wall means defining an opening in said commutator, said extension residing in said opening in said commutator whereby said commutator is rotated once for each orbit of said rotor, said shaft and rotor being rotatable together, the following equation holding true for said hydraulic device, namely:

$$R_2 + \frac{k_1 R_1}{k_2} < \frac{e}{k_2}$$

wherein,

R_2 =radius of said extension

R_1 =radius of said pivot member

k_2 =coefficient of friction for extension and wall means on commutator engagement

k_1 =coefficient of friction for pivot member rotatably mounting commutator

e =distance between extension axis and pivot member axis.

6. A hydraulic device comprising a casing, an internally toothed stator fixedly mounted within said casing, an externally toothed rotor mounted within said stator and having a lesser number of teeth than said stator, said rotor being capable of rotary movement about its own axis and orbital movement about the stator axis, said rotary and orbital movement of said rotor creating a plurality of alternately expanding and contracting chambers between the teeth on said rotor and on said stator, a rotatable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, pivot means rotatably mounting said commutator, a main shaft rotatably mounted in a position coaxial with said stator, an intermediate shaft having first and second portions, means connecting said first portion of said intermediate shaft to said main shaft and said second portion of said intermediate shaft to said rotor whereby said main shaft and said rotor rotate together and the axis of

said intermediate shaft describes generally the surface of a cone upon movement thereof, eccentric means for rotating said commutator and including an operating member operably connected at a first portion to said rotor and at a second portion to said commutator with said second portion spaced a distance from said pivot means whereby said commutator is rotated only in response to the orbital movement of said rotor, the following equation holding true for said hydraulic device, namely:

$$R_2 + \frac{k_1 R_1}{k_2} < \frac{e}{k_2}$$

wherein,

R_2 =radius of said second portion of said operating member

R_1 =radius of said pivot means

k_2 =coefficient of friction of said second portion of said operating member

k_1 =coefficient of friction of said pivot means

e =distance between axis of said second portion of said operating member and the axis of rotation of said pivot means.

7. A hydraulic device including in combination a casing having a bore, an internally toothed stator fixedly mounted in said casing bore and having an axis coaxial therewith, an externally toothed rotor having an axis and one less tooth than said stator and mounted within said stator for rotational movement with respect thereto and orbital movement whereby its axis orbits with respect to said stator axis, movement of said rotor relative to said stator creating a plurality of alternately expanding and contracting chambers between said rotor and stator teeth, a porting member fixedly mounted in said casing bore and having wall means defining a bore therethrough and first and second spaced faces, said first face of said porting member being positioned adjacent said rotor and stator, a commutator member mounted in said casing bore for rotatable movement and having wall means defining first and second spaced faces, said first face of said commutator member being positioned adjacent said second face of said porting member, inlet and outlet ports in said casing, said second face of said commutator member being located adjacent said inlet and outlet ports, said porting member having a plurality of circumferentially spaced ports extending from said first to said second face of said porting member, said ports at said porting member first face being aligned with respective chambers, said commutator member having wall means defining input and output passages, and each passage having a circumferential extent sufficient to encompass more than one of said circumferentially spaced ports, rotation of said commutator member causing said input and output passages to be alternately connected with each of said circumferentially spaced ports, a pin member having one end supported by said casing and coaxial with said stator, the other end of said pin member being received in an axial opening in said commutator member to rotatably mount said commutator member, a shaft coaxial with said stator and rotatably mounted, an operating member having a first portion connected to said shaft by a universal joint type connection, said operating member having a second portion connected to said rotor by a universal joint type connection whereby rotary movement is transmitted between said rotor and said shaft, said operating member having an extension extending axially of said rotor on the axis of said operating member and being displaced from said stator axis a greater distance than said rotor axis is displaced from said stator axis, wall means in said commutator member defining a drive opening displaced a given distance from said pin member, said extension of said operating member residing within said drive opening whereby said commutator member is ro-

11

tated in accordance with the orbital movement of said rotor and the rotary movement of said rotor is rendered ineffective, the radius of said pin member and the radius of said operating member extension being less than the distance between said pin member axis and said operating member extension axis divided by a coefficient of friction for the type of frictional contact between the moving members.

8. A hydraulic motor, comprising a first casing providing an internally toothed, generally cylindrical chamber, a rotor mounted in said chamber and having a lesser number of external teeth for hypocycloidal movement about the first casing chamber axis, said rotor having an axis offset from the first casing chamber axis and an axial splined bore extending therethrough, a second casing secured to said first casing on said one outer side and providing a chamber having a generally cylindrical inner wall defining an axis coaxial with said first casing chamber axis, a hydraulic fluid inlet passage extending generally radially of said second casing chamber and communicating said second casing chamber with the exterior of said second casing for supplying pressure fluid to said motor for actuating said rotor, a hydraulic fluid outlet passage extending generally axially of said second casing and communicating said second casing chamber with the exterior of said second casing for removing pressure fluid from said first casing chamber, said second casing being equipped with a plurality of flow passages, one for each tooth of said first casing chamber and communicating with said first casing chamber between adjacent teeth thereof, said second casing passages communicating with said second casing chamber a spaced distance inward of the second casing chamber inner wall, a generally cylindrical commutator rotatably mounted in said second casing chamber and having a bore extending therethrough parallel to the commutator axis, said bore being arranged to communicate with a first plurality of but less than all of said flow passages, said commutator having a notched peripheral portion arranged to communicate with a second plurality of but less than all of said flow passages, said second plurality being mutually exclusive of said first plurality, said notched peripheral portion being in constant communication with said inlet passage while said commutator bore is in constant communication with said outlet passage, a third casing secured to said first casing on the other outer side thereof and providing a generally cylindrical chamber coaxially related to said first casing chamber, an output shaft rotatably mounted in said third casing chamber and equipped with an axial splined bore extending partway therethrough from the end thereof adjacent said first casing, and a coupling pin interconnecting the bores of said shaft, rotor and commutator, said pin having a first peripheral splined portion at one end thereof engaging said shaft splined bore, and a second peripheral splined portion intermediate the pin ends engaging said rotor splined bore, said pin having a cylindrical portion on the other end thereof for engagement with said commutator bore, said pin having an axis inclined relative to the axes of all of said shaft, rotor and commutator to drive said shaft only in response to the rotary component of the hypocycloidal movement of said rotor and to drive said commutator only in response to the orbital component of the hypocycloidal movement of said rotor.

9. The structure of claim 8 in which said commutator is equipped with shaft means extending axially thereof and away from said rotor, said commutator bore having a portion concentric with said axis, and said outlet passage having a portion extending generally radially of said second casing and communicating with said concentric portion whereby said motor is adapted to provide two rotational outputs of different speeds.

10. A hydraulic device comprising an internally toothed member, an externally toothed member mounted within said internally toothed member and having a lesser

12

number of teeth than said internally toothed member, at least one of said internally and externally toothed members being capable of rotary movement about its own axis, one of said internally and externally toothed members being capable of orbital movement about the axis of the other of said members, said movement creating a plurality of alternately expanding and contracting chambers between the teeth on said internally and externally toothed members, a movable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, an amplifying member having first, second and third portions, said first portion of said amplifying member being operatively connected to the one of said internally and externally toothed members which is capable of orbital movement, said second portion being operatively connected to said movable commutator, and said third portion being fulcrumed to amplify movement of the second portion whereby said commutator moves in response to the orbital movement of the one of said internally and externally toothed members which is capable of orbital movement.

11. The device of claim 10 where the third portion of the amplifying member is coupled to a fixed axis shaft.

12. The hydraulic device of claim 11 wherein the amplifying member is a wobble stick universally coupled to the fixed axis shaft and to the orbiting toothed member.

13. The hydraulic device of claim 10 wherein the movable commutator is mounted for rotation on a fixed center axis.

14. In a hydraulic device comprising, input-output means rotatable on an axis, fluid displacement means having inner and outer parts which rotate and orbit relative to one another around said axis, an amplifying shaft part disposed at an angle with respect to said axis, means coupling said shaft part to one of said inner and outer parts at a first point along said shaft part and which first point orbits through a first orbital path relative to said axis, thereby orbiting said first point on said shaft part relative to said axis in unison with the fluid displacement means, a commutating porting means for said fluid displacement means and coupled to said shaft part at a second point along the length of said shaft part which orbits through a second orbital path relative to said axis, means fulcrumming said shaft part at a third point spaced from said first point, said second orbital path amplified to be larger than said first orbital path in proportion to the angularity of the shaft part and the spacing of said points along the length of the shaft part, whereby the commutating porting means will be driven at orbit speed.

15. A hydraulic device comprising an internally toothed member, an externally toothed member mounted within said internally toothed member and having a lesser number of teeth, one of said internally and externally toothed members being capable of rotary movement about its own axis and orbital movement about the axis of the other of said members, said rotary and orbital movement creating a plurality of alternately expanding and contracting chambers between the teeth on said members, a movable commutator for controlling the entrance and exit of fluid from said alternately expanding and contracting chambers, a main shaft rotatably mounted in a position coaxial with the other of said internally and externally toothed members, an intermediate shaft having first and second portions, means connecting said first portion of said intermediate shaft to said main shaft and said second portion of said intermediate shaft to said one of said internally and externally toothed members whereby said main shaft and said one of said internally and externally toothed members rotate together and the axis of said intermediate shaft describes generally the surface of a cone upon movement thereof, and means coupling said one of said internally and externally toothed members and commutator together for moving said commutator only in response to the orbital movement of

13

said one of said internally and externally toothed members.

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14

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