United States Patent [19]

Kilmer

[11] **3,905,727**

[45] **Sept. 16, 1975**

[54] **GEROTOR TYPE FLUID MOTOR, PUMP OR THE LIKE**

[76] Inventor: **John B. Kilmer,** 900 S. 8th St., Lamar, Colo. 81052

[22] Filed: **Mar. 7, 1974**

[21] Appl. No.: **448,993**

Related U.S. Application Data

[62] Division of Ser. No. 166,672, July 28, 1971, Pat. No. 3,796,525.

[52] **U.S. Cl.** ..... **418/61 B;** 418/186

[51] **Int. Cl.²** **F01C 1/02;** F03C 3/00; F04C 1/02

[58] **Field of Search** ..... 418/61 R, 61 A, 61 B, 186

[56] **References Cited**

UNITED STATES PATENTS

448,607	3/1891	Gollings	418/61 R
3,389,618	6/1968	McDermott	418/61 B
3,431,863	3/1969	Waldorf	418/61 B

FOREIGN PATENTS OR APPLICATIONS

1,811,386	6/1970	Germany	418/61 B
202,323	4/1939	Switzerland	418/64
392,327	3/1924	Germany	418/61 R

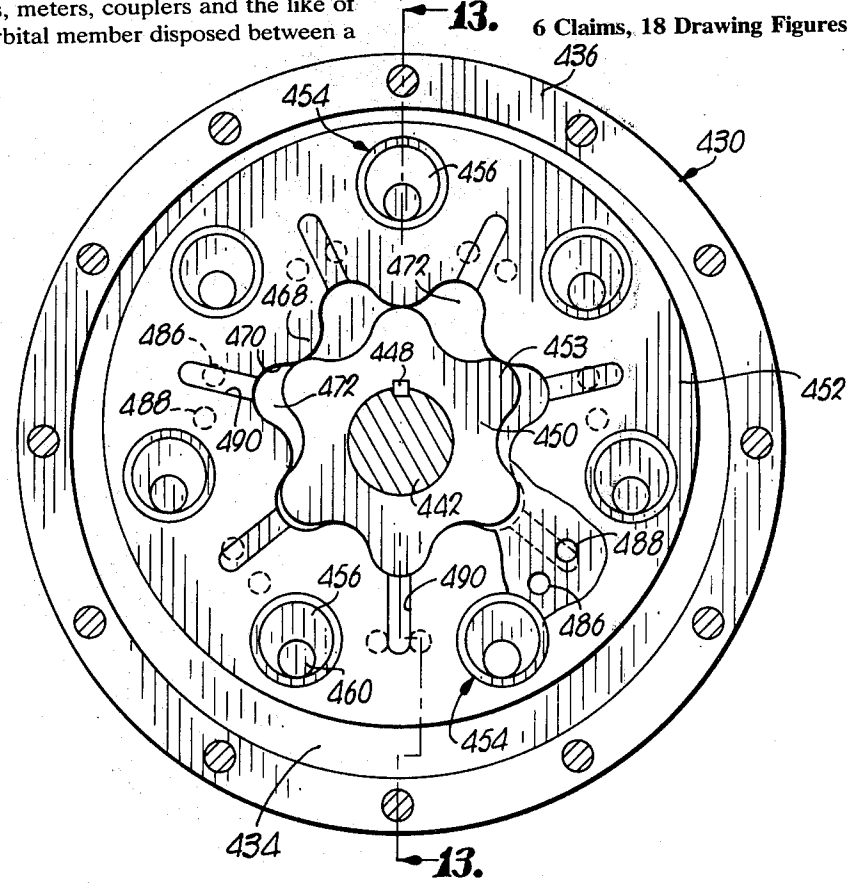
Primary Examiner—John J. Vrablik

Attorney, Agent, or Firm—Schmidt, Johnson, Hovey & Williams

[57] **ABSTRACT**

Improved fluid-mechanical and mechanical-fluid energy translation devices, such as fluid motors, pumps and certain actuators, meters, couplers and the like of the type having an orbital member disposed between a rotor element and a stator element and coupled with one of the elements by fluid displacement means and with the other element by gear means, are provided by employing therein a plurality of eccentric means for positively but shiftably mounting the member upon the element to which it is coupled by fluid displacement means in manner restricting relative motion between the member and the last-mentioned element to relative orbital motion. The element upon which the member is thus mounted may be either a rotor or a stator element and may be either the inner or the outer of the elements in various embodiments of devices incorporating the invention. The eccentric means, which are essentially cranks or shafts with offset axes, significantly are alone sufficient to accomplish the positive, shiftable mounting of the member and the restriction of same to relative orbital motion and to do so quite independently of any other fluid and mechanical couplings that may exist between the member and the elements in various particular forms of devices. The preferred embodiment also provides a further improvement in devices of this type employing vanes to define fluid displacement chambers by arranging the parts to maintain the pair of vanes bounding each chamber parallel to each other throughout the operating cycle, thereby maintaining the chordal transverse cross-sectional area of each chamber substantially constant throughout such cycle. The devices embodying the invention are characterized by increased efficiency and reliability, reduced wear on certain primary parts, and greater economy of manufacture by virtue of reduced strength and looser tolerance requirements in connection with certain primary parts.

6 Claims, 18 Drawing Figures



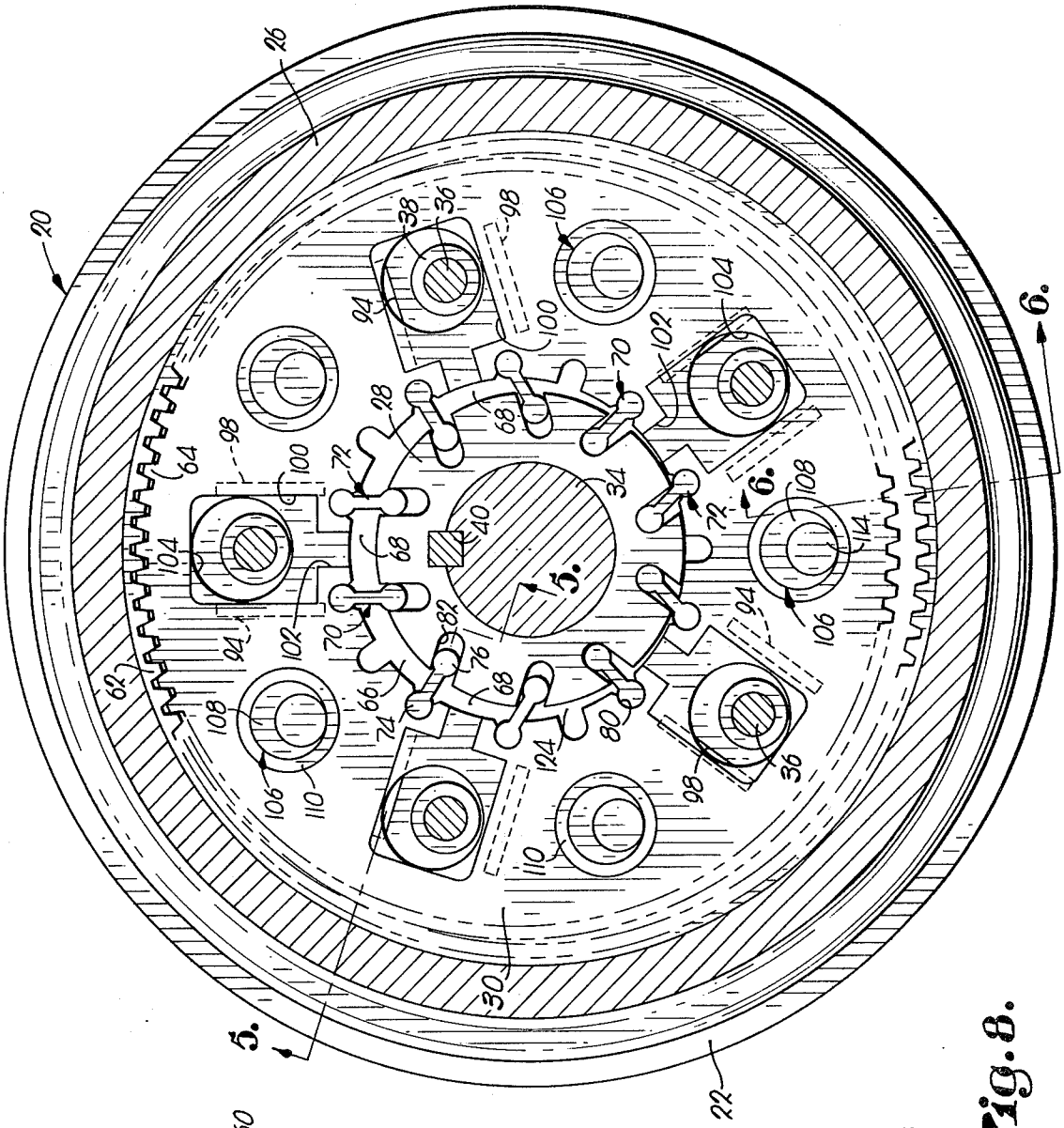


Fig. 3.

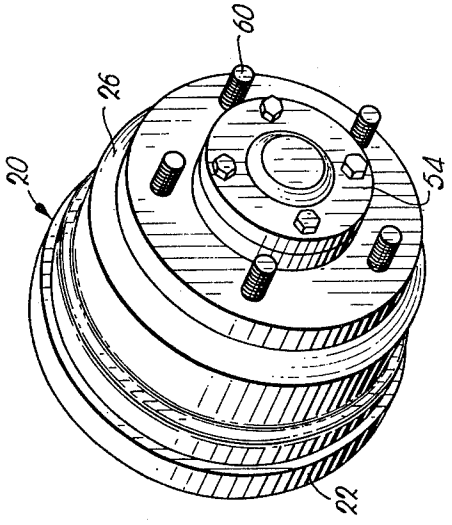


Fig. 1.

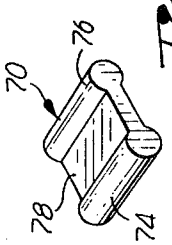


Fig. 8.

Fig.6.

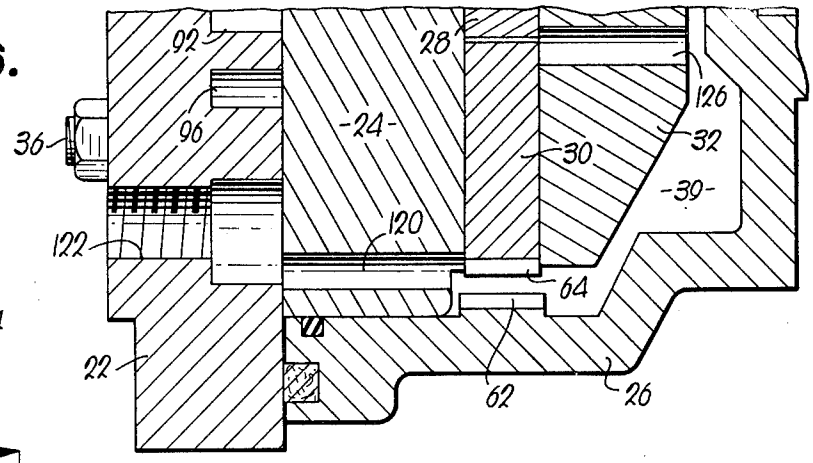


Fig.7.

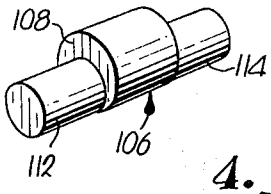


Fig.2

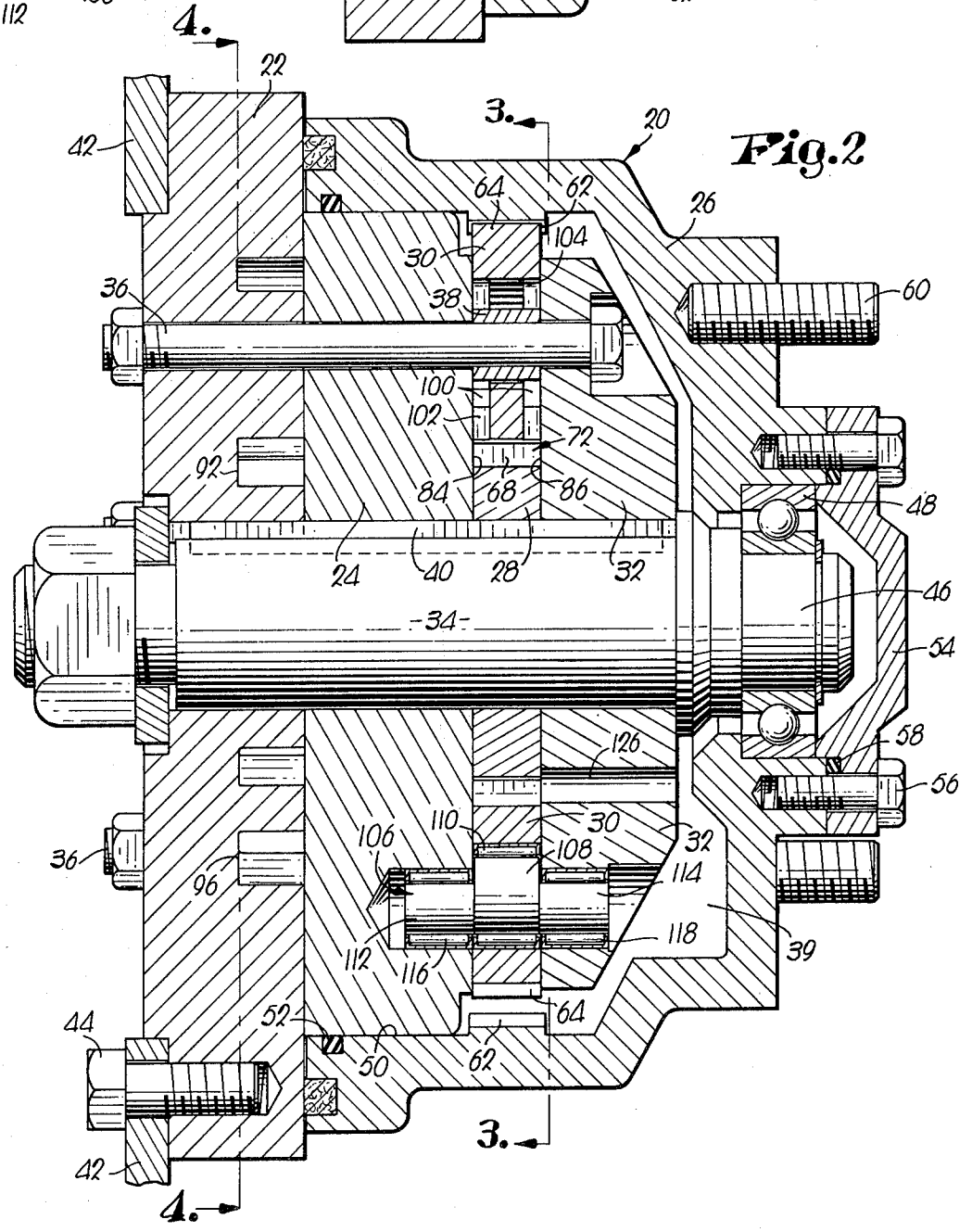


Fig.5.

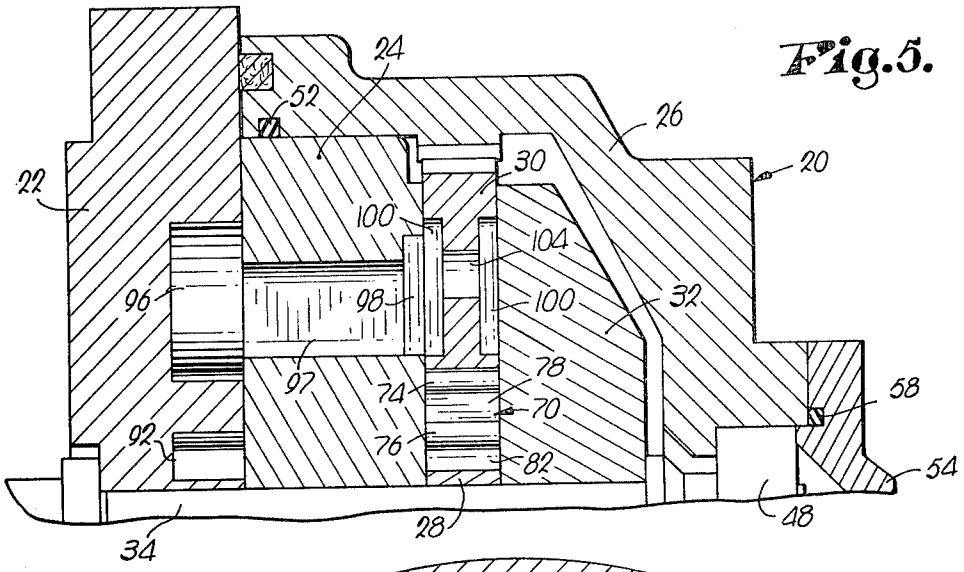
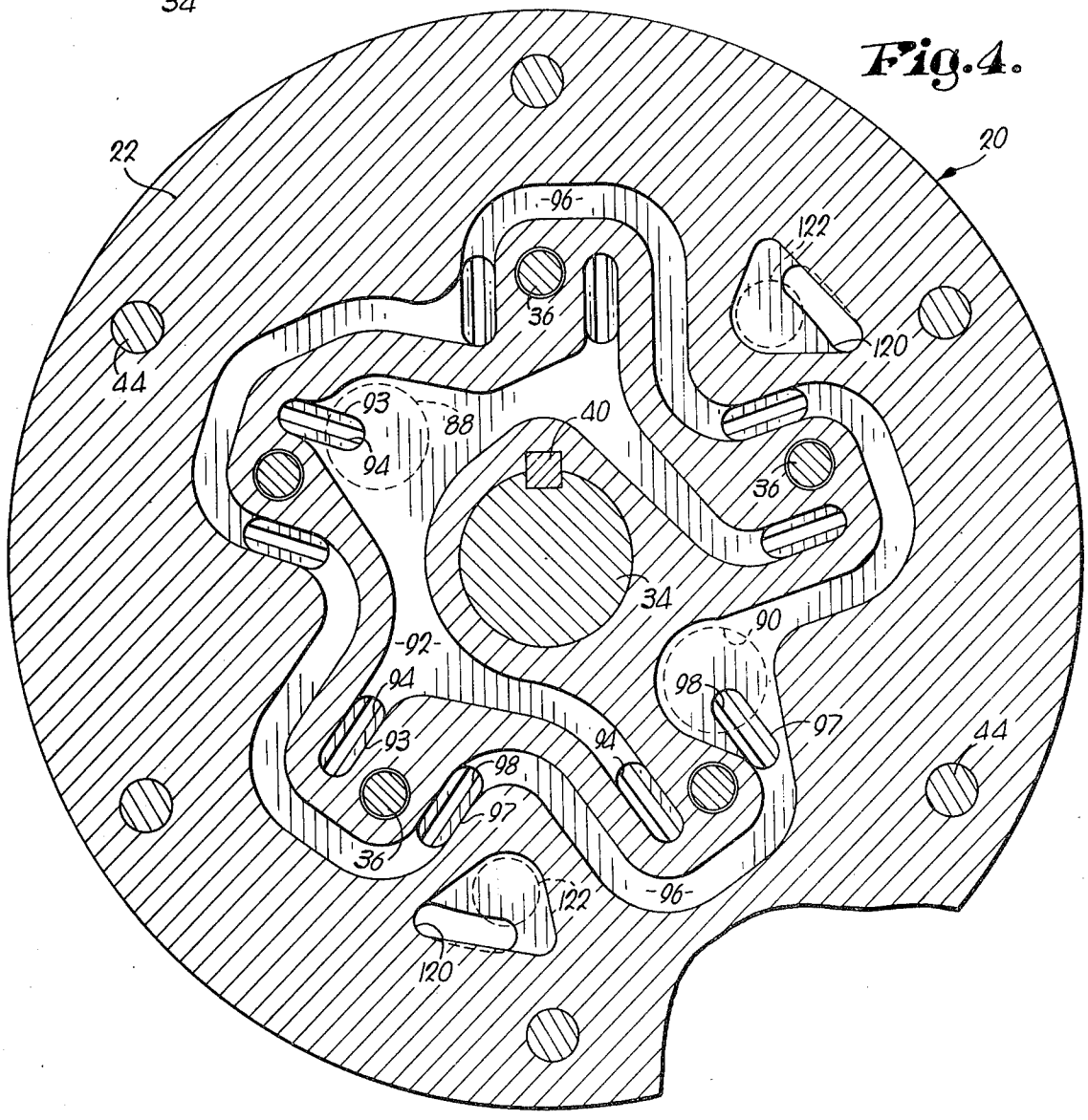

24
52
26
30
20
22
100
104
96
98
100
32
97
78
74
70
58
92
76
82
54
28
48
34

Fig.4.


22
20
96
122
36
120
44
93
88
40
94
36
34
90
92
98
94
97
93
94
44
98
97
36
122
96
120

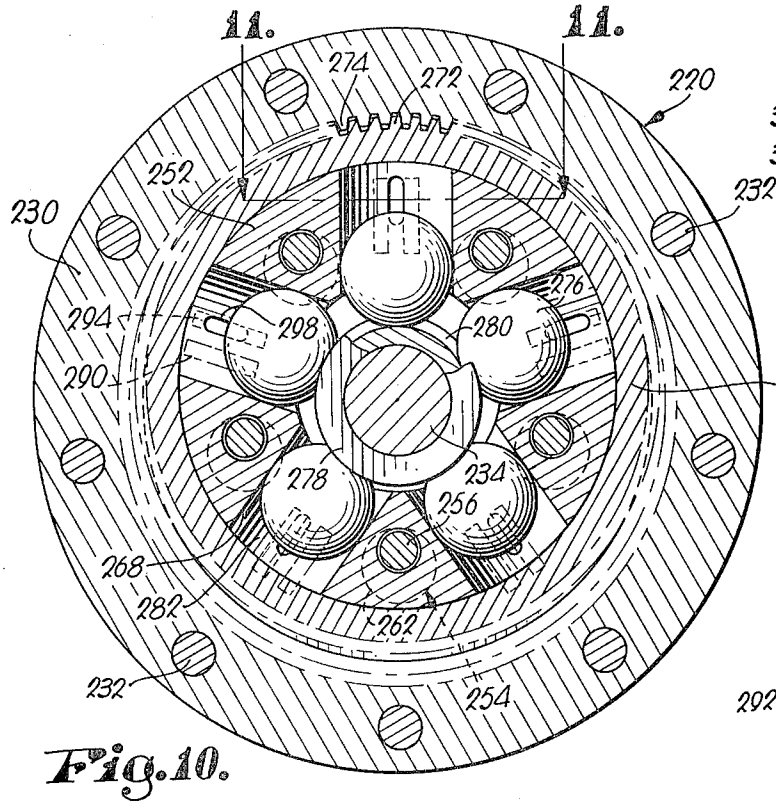


Fig.10.

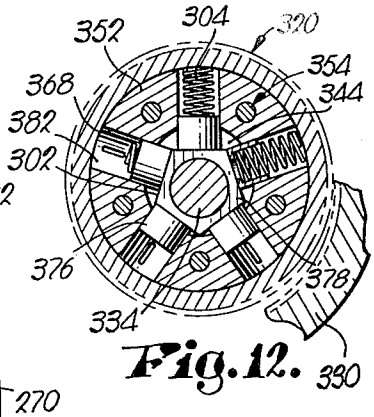


Fig.12.

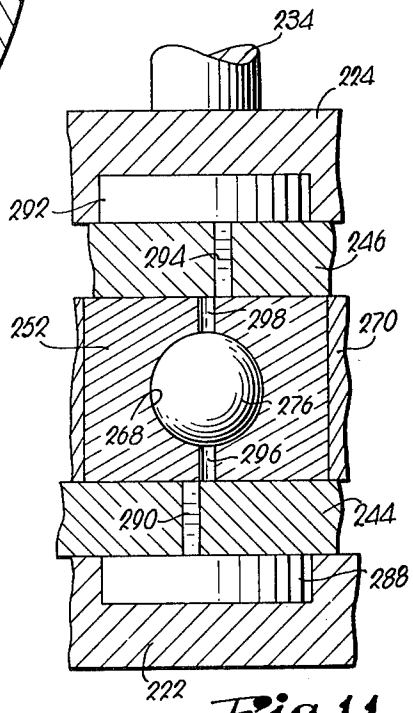


Fig.11.

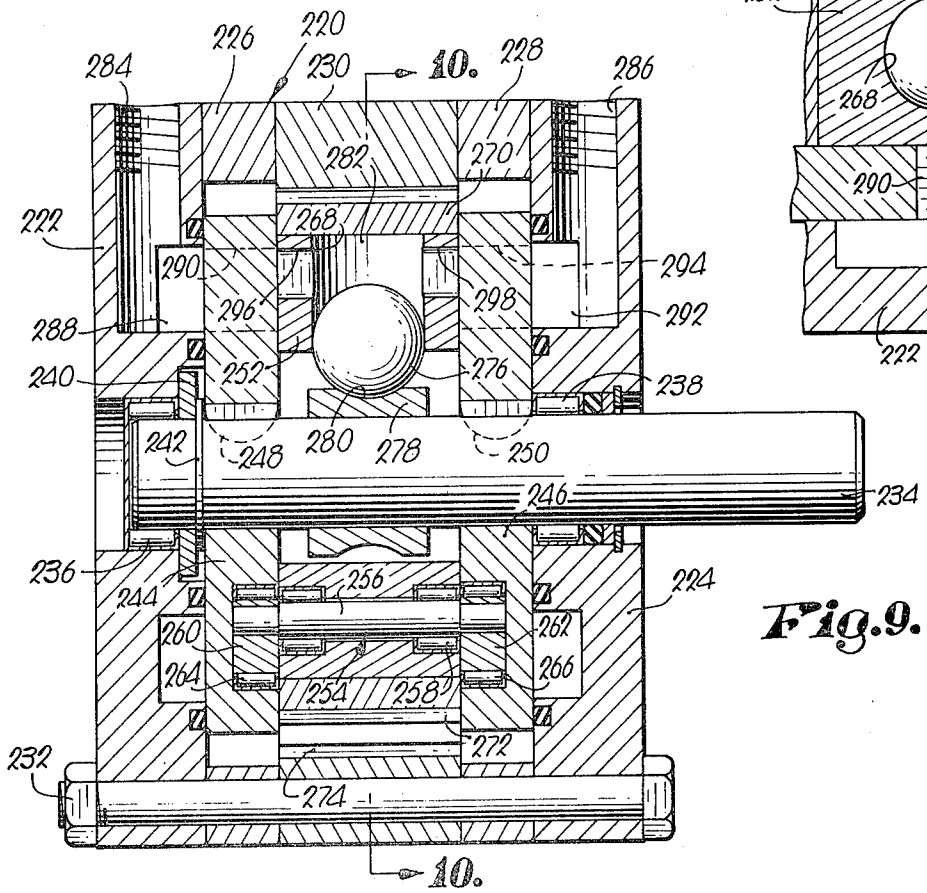


Fig.9.

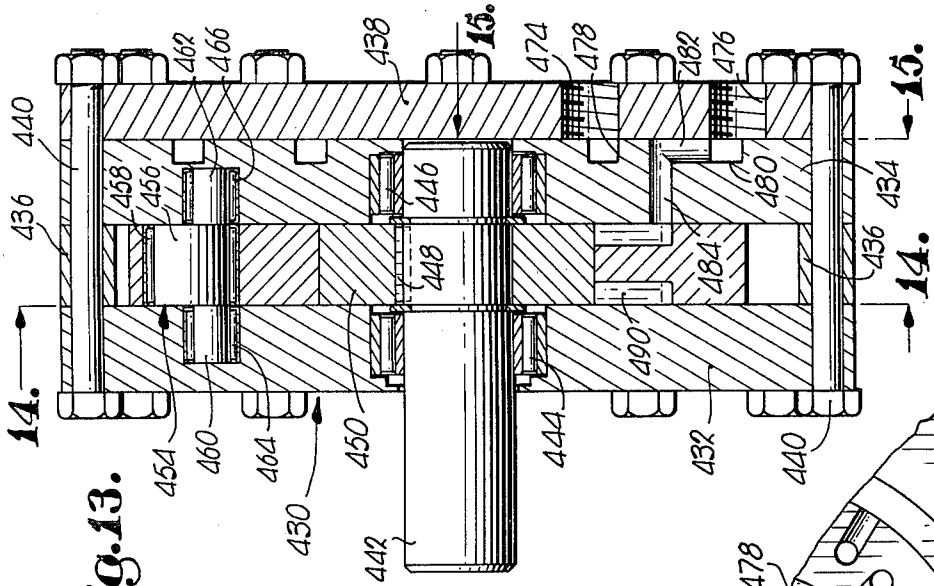


Fig.13.

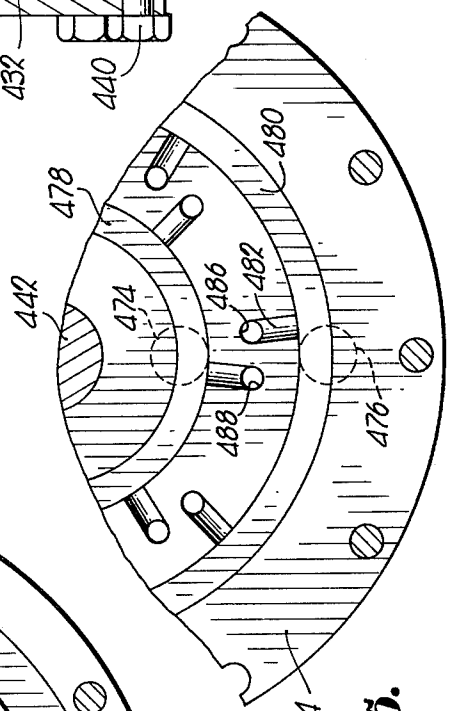
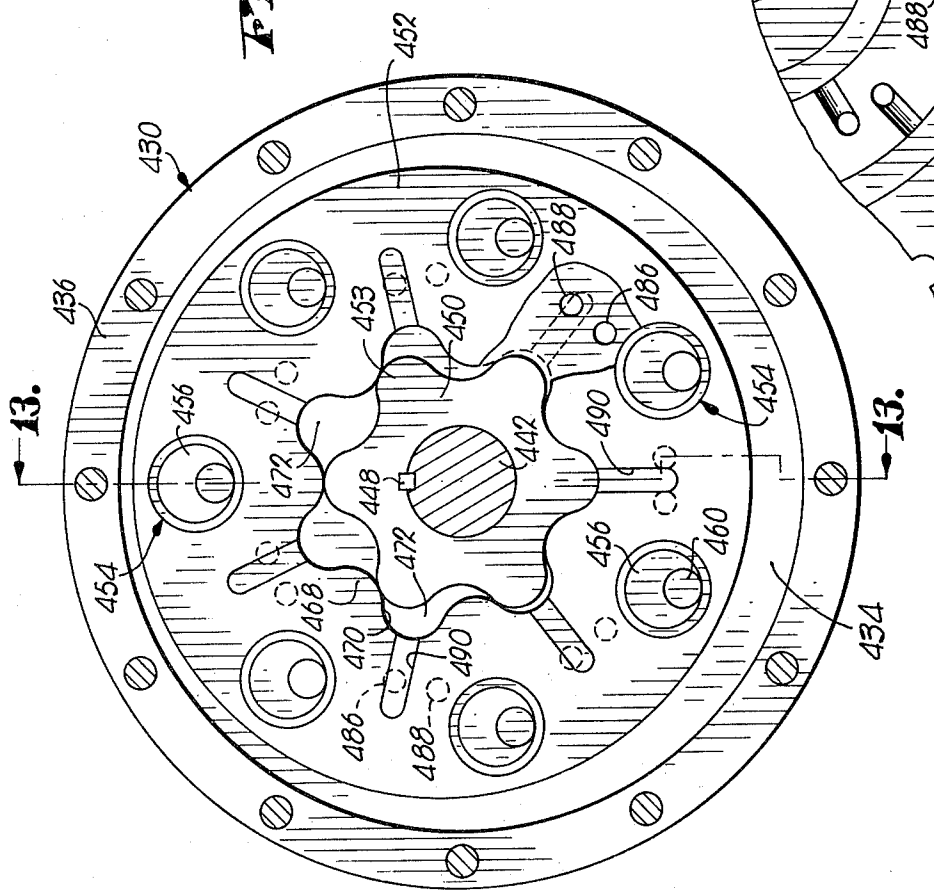


Fig.15.

Fig.14.



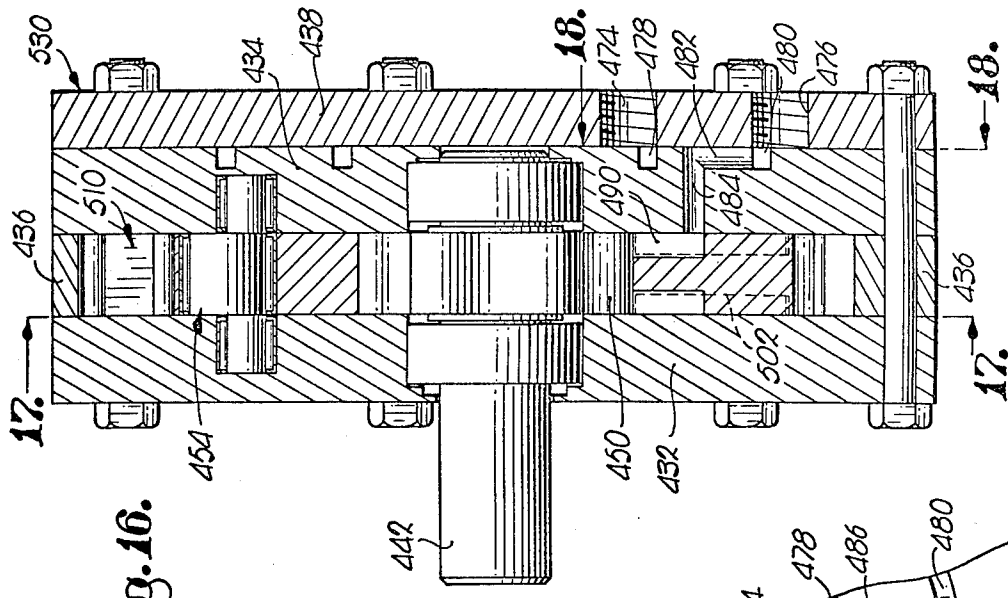


Fig. 16.

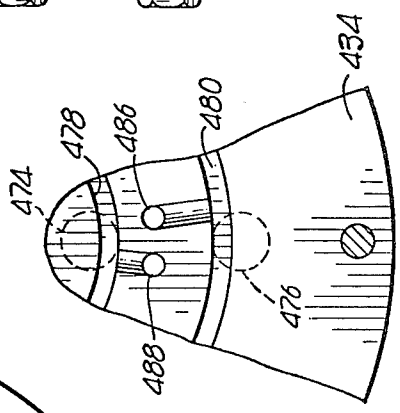


Fig. 18.

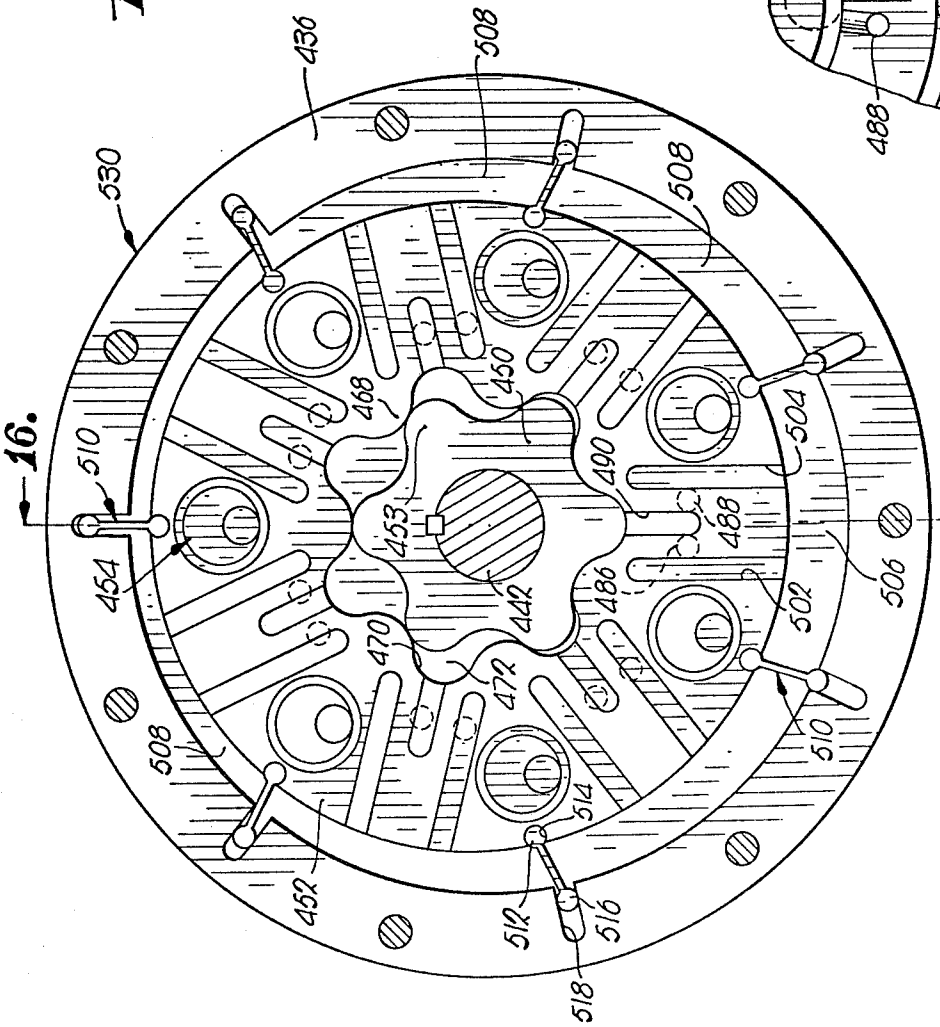


Fig. 17.

GEROTOR TYPE FLUID MOTOR, PUMP OR THE LIKE

This is a division, of U.S. application Ser. No. 166,672, filed July 28, 1971 now U.S. Pat. No. 3,796,525.

This invention relates to energy translation devices and, more particularly, to that class of devices employed for translating energy in the form of fluid pressure into energy in the form of mechanical rotation or vice versa, which commonly include devices employable as fluid pressure driven motors or conversely as pumps, as well as certain devices employable as actuators, meters, couplers and the like. Still more specifically, the invention is concerned with improvements in such devices of the type having a pair of spaced-apart, concentric, relatively rotatable machine elements and an orbital machine member disposed therebetween and operably coupled with at least one of the machine elements by fluid displacement means and with at least one of the machine elements by mechanical coupling means typically in the form of what is commonly called epicyclic gearing.

Devices of the general class to which the invention pertains and which employ a pair of relatively rotatable machine elements in combination with an intermediate orbital machine member therebetween assume a variety of forms, suitable examples of which may be found in the following patents:

U.S. Patent No.	Title	Patentee	Granted
3,215,043	Hydraulic Torque Motors	M. J. Huber	Nov. 2, 1965
3,391,608	Hydraulic Torque Motor	M. J. Huber	July 9, 1968
3,490,383	Hydraulic Pump Or Motor	J. T. Parrett	Jan. 20, 1970
3,516,765	Fluid Actuated Actuator	Boyadjieff et al	June 23, 1970

Although prior devices of the general class perform satisfactorily in many applications they are typically subject to various limitations and disadvantages peculiar to the particular construction thereof, many of which appear to be attributable to the fact that the orbiting member is normally "floated" between the inner and outer machine elements so that the device must depend upon the interfacing of epicyclic gear faces on one element and the orbital member to confine the latter to an orbital path of motion, as well as to produce the desired relative rotation between such element and the member. The mentioned conventional relationship between the orbiting member and the machine elements between which it is interposed, result in a necessity for constructing the epicyclic gear faces with substantially greater strengths and tighter tolerances than would be required if the epicyclic gear mechanism was not required to confine the orbiting member to its orbital path, as well as to produce relative rotation. Moreover, when the epicyclic gearing itself is employed to confine the orbiting member to its orbital path, the increased friction and strains, which can be very substantial in this class of device, result in undue wear and sometimes breakage to the epicyclic gearing structure. The same factors have also been found to seriously limit the efficienty of operation that may be achieved with a device of given construction.

Accordingly, it is the primary object of this invention to provide improved devices of the mentioned class in

which the aforesaid and other limitations and disadvantages of conventional constructions are overcome.

It is another important object of this invention to provide such improved devices in which operating efficiency and reliability are increased, and in which wear upon the epicyclic gear structure is decreased.

It is another important object of the invention to provide such an improved device which can be manufactured more economically than conventional devices for comparable purposes by virtue of the lower strength factors and looser tolerances tham may be employed particularly in connection with the epicyclic gear structure.

It is another important object of the invention to provide such improved devices in which the orbital machine member is positively but shiftably mounted upon one of the machine elements by means of a plurality of freely rotatable eccentric crank or shaft mechanism which are operable, independently of any other fluid or mechanical coupling that may exist between the orbiting member and the machine elements, to support and confine the motion of the orbital member relative to the machine element upon which it is thus mounted to free orbital movement.

It is another important object of the invention to provide such improved devices in which any requirement for a 1:1 gear mesh between the orbiting member and a frame element, as required in many conventional devices in which the orbital member "floats", is eliminated, and in which the epicyclic gear surface associated with the orbital member may be provided on the outer circumference of the latter with resultant reduction of loads and stresses upon the teeth thereof.

Another important object of the invention is to provide such improved devices in which the orbital movement of the orbital member may be employed to accomplish directly the valving employed to control the supplying and exhausting of fluid from an annular series of displacement chambers on a progressively cycled basis.

Another important object of this invention is to provide such improved devices in which operating efficiency is improved by the employment of pairs of shiftable, displacement chamber bounding vanes extending between the orbital member and one of the machine elements and which remain parallel to each other throughout the operating cycle to maintain the chordal transverse cross-sectional area of each chamber substantially constant throughout such cycle, so that the rate of fluid flow into and out of individual displacement chambers may be kept in phase with the areas of opening of input and exhaust valves which are controlled in sinusoidal fashion by the movement of the orbital member, as contrasted with conventional constructions in which the effective cross-sectional area of the chamber or piston is a function of the stroke posi-

tion so that fluid flow is not precisely phased with valve operation.

Another important object of this invention is to provide such improvements for a wide variety of the class of devices mentioned, and particularly, to provide for positive mounting and confinement of the orbiting member to an orbital path by eccentric means operable independently of any other mechanical or fluid couplings in device constructions as diverse as vane defined chamber devices, radical ball piston devices, hollow cylinder virtual piston devices, and gerotor devices.

Another important object of this invention is to provide devices employing the mentioned improvements which are further characterized by the use of fluid couplings between the orbital member and both of the machine elements.

Still other objects of the invention, including certain significant details of construction, will be made clear or become apparent to those skilled in the art from the accompanying drawings and the description of illustrative embodiments of the invention that follows.

In the accompanying drawings:

FIG. 1 is a perspective view of a currently preferred energy translation device embodying the invention;

FIG. 2 is a central cross-sectional view of FIG. 1 taken through the axis thereof;

FIG. 3 is a cross-sectional view taken on line 3—3 of FIG. 2;

FIG. 4 is a cross-sectional view taken on line 4—4 of FIG. 2;

FIG. 5 is a fragmentary, enlarged, cross-sectional view taken on line 5—5 of FIG. 3;

FIG. 6 is a fragmentary, enlarged, cross-sectional view taken on line 6—6 of FIG. 3;

FIG. 7 is a perspective view of one preferred embodiment of eccentric shaft employed in the device of FIG. 1;

FIG. 8 is a perspective view of one of the vanes employed in the device of FIG. 1;

FIG. 9 is a central cross-sectional view of another embodiment of energy translation device incorporating the invention taken on the axis of such device;

FIG. 10 is a cross-sectional view taken on line 10—10 of FIG. 9;

FIG. 11 is a fragmentary, cross-sectional view taken on line 11—11 of FIG. 10;

FIG. 12 is a transverse cross-sectional view of another embodiment of energy translation device incorporating the invention;

FIG. 13 is a central cross-sectional view of still another embodiment of energy translation device incorporating the invention taken through the axis thereof;

FIG. 14 is a cross-sectional view taken on line 14—14 of FIG. 13;

FIG. 15 is a fragmentary, cross-sectional view taken on line 15—15 of FIG. 13;

FIG. 16 is a central cross-sectional view of still another embodiment of energy translation device incorporating the invention;

FIG. 17 is a cross-sectional view taken on line 17—17 of FIG. 16; and

FIG. 18 is a fragmentary, cross-sectional view taken on line 18—18 of FIG. 16.

Referring first to FIGS. 1-8 inclusive, the preferred embodiment of the invention will be illustrated and described in connection with the device generally designated 20. The device 20 broadly includes a manifold 22, a valve and bearing block 24, an outer hub element 26, an inner element 28, an orbiting ring member 30, an end plate 32 and a main shaft 34. The manifold 22, the block 24, the inner element 28, and the end plate 32 are all secured together as a unit by the main shaft 34 and by bolt means as at 36, with a spacer 38 being provided between the block 24 and the plate 32 around each bolt 36. The group of parts just mentioned are all also keyed to the main shaft 34 by a key as at 40. The axial dimension of spacers 38 and inner element 28 is slightly greater than the axial dimension of orbiting member 30 to provide running clearance for the member 30 in fluid sealed relationship between block 24 and plate 32. For illustrative purposes, in a typical application of the device 20, the manifold 22, block 24, inner element 28, plate 32 and main shaft 34 may all be stationary and can be mounted on a base frame 42 of other equipment by means of bolts as at 44. The outer hub element 26 is rotatably mounted upon an end portion 46 of main shaft 34 by suitable ball bearing means as at 48, and a sleeve bearing support surface 50 is also provided between the hub element 36 and the block 24, a seal being effected between the hub 26 and block 24 by an O-ring as at 52. The extremity of hub 26 adjacent end portion 46 of the shaft 34 is preferably sealed by a removable cap 54 held in place by bolts as at 56, with an O-ring seal as at 58.

In the embodiment of device 20 chosen for illustration, it will be perceived that the outer hub element 26 is rotatable relative to the inner element 28, as well as the manifold 22, the block 24 and the plate 32, about the axis of the main shaft 34. Accordingly, the hub element 26 is provided with a plurality of threaded studs 60 extending therefrom to facilitate mechanical coupling of the hub element 26 with an external rotatable assembly. When the device 20 is powered from a source of fluid under pressure, as hereinafter more fully described, the device 20 functions as a fluid-driven motor which is particularly adapted to low-speed, high-torque application, and it will be understood that the outer, rotatable hub element 26 is then rotationally driven by the action of device 20 so that the studs 60 would be employed to couple the hub to an external assembly to which such rotational power of the hub 26 is to be imparted. On the other hand, those skilled in the art will appreciate that the device 20 may alternately be employed as a fluid pump, in which case the studs 60 will be used to couple the rotatable outer hub element 26 to a rotating, powered external assembly for rotationally driving the outer hub element 26 of the device 20. For convenience in describing the device 20, reference will initially be made to certain aspects of the construction and operation of the device 20 in the context of its application as a fluid driven motor.

Referring now particularly to FIG. 3, in conjunction with FIG. 2, it will be seen that the outer hub element 26 is provided on its inner circumference with a set of inwardly facing gear teeth 62 aligned with a set of outwardly facing gear teeth 64 on the outer surface of the generally ring-shaped orbiting member 30. The teeth 62 and 64 together present what is normally referred to as an epicyclic gear transmission or coupling between the orbiting member 30 and the outer rotatable hub element 26, it being understood that there will be a lesser number of teeth 64 on the member 30 than there are teeth 62 on the element 26, but that the sets of teeth 62 and 64 are appropriately shaped for proper meshing

as the member **30**, which is of lesser outer diameter than the corresponding inner diameter of hub element **26**, orbits within the latter. Thus, it will be perceived that, assuming the provision of some means for orbiting the member **30** while constraining the same against rotation, the teeth **64** will "walk" with respect to the teeth **62** on hub element **26**, thereby driving and imparting rotational movement to the latter.

The inner diameter of the orbiting member **30** is somewhat larger than the outer diameter of the inner element **28**, presenting a space **66** therebetween. A plurality of fluid displacement chambers **68** are formed within the space **66** by pairs of vanes **70** and **72**. As best shown in FIG. **8**, each of the vanes **70** or **72** includes a pair of cylindrical end portions **74** and **76** interconnected by a web portion **78**. The cylindrical portion **74** of each vane **70** or **72** is pivotally but captively received within a cylindrical slot **80** in the inner circumferential face of the orbiting member **30** while the opposite cylindrical end portion **76** is pivotally and slidably received within a corresponding elongated slot **82** formed in the outer circumferential surface of the inner member **28**. Any number of three or more of the fluid displacement chambers **68** may be used, depending upon the size and intended application of the device **20**, the illustrated embodiment utilizing five of such chambers **68**. It will be understood that, when fluid under pressure is introduced into a particular chamber **68** as hereinafter more fully described and as occurs during utilization of the device **20** as a motor, the vanes **70** and **72** defining the lateral extent of such chamber will be urged apart to effect a sealing contact between the vane portions **74** and **76** and the corresponding surfaces of slots **80** and **82**. With the chamber **68** thus sealed, as further fluid is introduced therein, the fluid pressure within such chamber **68** will force the adjacent portion of the orbiting member **30** away from the opposing surface of stationary inner element **28**. While one chamber **68** is being supplied with fluid under pressure, the chamber or chambers **68** on the opposite side of the orbiting member **30** will be having fluid exhausted therefrom, and such relationship is caused to progress circularly from each chamber **68** to an adjacent chamber **68** by the valving and control means hereinafter described. Accordingly, the fluid being continuously introduced into certain chambers **68** while being exhausted from other chambers **68** and the rotary progression of such relationships during the operating cycle exert forces upon the member **30** tending to make the latter move in an orbital path with respect to the axis of shaft **34** and the outer and inner elements **26** and **28** respectively.

As will be noted from FIG. **3**, the vanes **70** and **72** bounding the sides of each displacement chamber **68** are adapted to pivot within the slots **80** and to pivot and slide within the slots **82** as required to accommodate the orbital movement of the member **30**. As will be further significantly noted, however, the slots **80** and **82** are so juxtaposed that each pair of vanes **70** and **72** will be and always remain substantially parallel to each other regardless of the direction or degree in which both are pivoted to accommodate the orbital movement of the member **30**. Since the other lateral faces of each chamber **68** are closed by the parallel surfaces **84** and **86** of block **24** and plate **32**, the parallelism of each vane **70** with its associated vane **72** assures that the chordal transverse cross-sectional area of the chamber **68** therebetween will remain substantially constant. This is in sharp contrast with the conventional practice of disposing all of the chamber defining vanes in this class of device essentially radially of the central axis of the device, which results in a nonlinear rate of change in the volume of the enclosed chamber with respect to the stroke or instantaneous positioning of the orbiting member at different times during the operating cycle. It has been found that maintaining the chordal transverse cross-sectional area of the chambers **68** constant throughout the operating cycle substantially increases efficiency by maintaining fluid flow rates to and from the chambers **68** precisely in phase with the sinusoidal variance in valve opening areas conveniently provided by using the orbiting motion of the member **30** to open and close valve apertures, in the manner now to be described.

Referring now also to FIG. **4**, the device **20** is provided with a pair of fluid ports **88** and **90** which may be an inlet port and an outlet port respectively. Ports **88** and **90** are adapted to be coupled with the pressure and return sides of an external source of hydraulic system oil or other suitable fluid pressure, when the device **20** is being used as a motor. In passing, it should be noted that the device **20** is reversible and that the directions of orbiting of the member **30** and rotation of the element **26** may be reversed merely by reversing the flow of fluid to and from the ports **88** and **90**. The port **88** communicates with an irregular passage **92** within the manifold **22**, which in turn communicates with a plurality of openings **93** each terminating in an elongated slot-like opening **94** in the face of block **24** adjacent the member **30**, there being such an opening **94** for each of the chambers **68**. Similarly, the port **90** communicates with an irregular passage **96** formed in the manifold **22**, which in turn communicates with a plurality of openings **97**, each terminating in an elongated slot-like opening **98** in the face of block **24** adjacent the member **30**, it being noted that there is an opening **98** for each opening **94** and that they are arranged in parallel pairs corresponding to each of the chambers **68**.

Referring now back to FIGS. **2** and **3**, in conjunction with FIG. **4**, it will be seen that adjacent each chamber **68** the opposing faces of the orbiting member **30** are relieved or cutaway as at **100** and **102** to provide a fluid flow passage **100-102** communicating with the corresponding chamber **68** and to provide hydraulic balancing of member **30** between block **24** and plate **32**. The pair of passage portions **100** for each chamber **68** communicate with each other through a relatively large circular opening **104** through the orbiting member **30**, which is also adapted to provide clearance for the bolts **36** and spacers **38** without engagement between the spacers **38** and the orbiting member **30**. Thus, it will be seen that fluid may flow freely to or from each chamber **68** through the opposed neck passages **102** and the generally rectangular passages **100** that are intercommunicated by the corresponding opening **104**. Since the fluid forces acting between member **30** and block **24** and between member **30** and plate **32** are balanced, member **30** axially floats between block **24** and plate **32**, although it is otherwise positively mounted for guidance in an orbital path as hereinafter described.

The openings **94** and **98** are indicated by dotted lines in FIG. **3** and will be seen, with reference to the topmost chamber **68** of FIG. **8**, to be spaced apart just sufficiently that the relieved passages **100** may be posi-

tioned therebetween and in communication with neither when the orbiting member **30** is in a position at which the fluid connection to such chamber **68** is just being changed from a pressure to an exhaustion phase of the fluid cycling of such chamber **68.** Referring to the chamber **68** located at approximately two-o'clock in FIG. **3,** however, it will be seen that the fluid inlet opening **94** is fully aligned and communicating with the corresponding relieved passages **100,** while the associated exhaust opening **98** is completely out of communication with the passage **100.** The relieved passages **100** associated with the other chambers **68** are in differing progressive relationships with their associated inlet opening **94** and exhaust opening **98,** so that as the member **30** moves orbitally with respect to the axis of shaft **34** the chambers **68** will each be successively subjected to first an input of fluid under pressure of flow rate increasing to maximum then waning to minimum, then reversing direction for exhausting fluid at a rate also increasing to maximum then waning to minimum before the commencement of the next input or pressure phase. The openings **94** and **98** are so disposed within the block **24,** with respect to the location of the passages **100** in the member **30,** that the mentioned progressive cycling of each chamber **68** through its fluid input and fluid exhaust phase will be controlled automatically by the orbiting of the member **30** with the areas of valve opening communication between the openings **94** and **98** and the passages **100,** as well as the rates of flow of fluid therethrough, varying sinusoidally. It will also be noted that while the chambers **68** on one side of the member **30** are being subjected to pressure, those on the other side will be in their exhaust phase to enhance and maintain the orbital movement of the member **30.**

With the structure thus far described, those skilled in the art will appreciate that, without the provision of further means for guiding and confining the member **30** to an orbital path. the teeth **62** and **64** would have to be formed to close tolerances to properly guide the member **30** and would also have to be of particularly sturdy construction in order to bear the substantial forces that would be imposed thereon, and that, even with such a construction, the friction and wear upon the teeth **62** and **64** would inevitably be substantial as is common in conventional devices; actually, since the bolts **36** and spacers **38** do not and are not intended to engage the inner surfaces of clearance openings **104,** it will also be clear that the member **30** would tend to rotate as well as orbit with respect to the inner element **28** to an extent further complicating the problem or perhaps even rendering the apparatus inoperable. The objects of the invention are, therefore, attained in the device **20** by the provision of a plurality of three or more eccentric crank or shaft assemblies generally designated **106** (see particularly FIGS. **2, 3** and **7**). Each eccentric assembly **106** may include a central cylindrical portion **108** journaled by needle bearings **110** within the orbiting member **30,** and a pair of oppositely extending cylindrical portions **112** and **114** of smaller diameter than the portion **108** and having a central axis offset from the central axis of the portion **108.** The eccentric end portions **112** and **114** are respectively journaled in the valving block **24** and the end plate **32** by needle bearings **116** and **118.** In the preferred illustrative device **20,** five of the assemblies **106** are utilized for convenience in spacing the same between the valving means associated with each of the five chambers **68** employed in such device. It should be noted, however, that any number greater than two of such assemblies **106** may be employed, although it is preferable to use a number of assemblies **106** that may be equally spaced around the member **30** without interference with the valving means associated with the particular number of equally spaced chambers **68** that are to be employed. The offset between the axis of the portions **112** and **114** with respect to the axis of the portion **108** is so chosen as to permit exactly the range of orbital movement of the member **30** needed to bring the teeth **64** into proper "walking" mesh with the teeth **62** as the member **30** is orbited.

The assemblies **106** are found to add very little friction to the device and considerably less than that encountered where meshing gears must be relied upon to provide orbital guidance for the member **30.** The assemblies **106** are operably sufficient, independently of any other structures or relationships in the device **20,** to positively but freely and shiftably mount the member **30** upon the stationary portions of the device **20** including the inner element **28** and to guide and confine the movement of the member **30** to a perfect orbital path with respect to the axis of the shaft **34.** In so doing, it will be apparent that the assemblies **106** increase efficiency, decrease wear and lower manufacturing costs by decreasing the material strengths and tolerances necessary in constructing various parts including particularly the epicyclic gear teeth **62** and **64.**

The other constructional details of the device **20** are substantially conventional and may vary to a considerable extent as those skilled in the art will appreciate. For the sake of completeness, however, it is noted that the embodiment of device **20** chosen for illustration is provided with a cavity **39** (see FIG. **6**) for collecting fluid that may normally be expected to leak around the vanes and through the running clearances between the parts, which fluid may then be drained through a passage **120** in the valving block for removal through a communicating drain port **122** provided in the manifold. It will also be noted that redundant fluid displacement chambers are formed as at **124** between the functional fluid displacement chambers **68,** and provision for venting such redundant chambers **124** is made by passages **126** extending therefrom through the end plate into communication with the collection cavity **39,** which avoids trapping or cavitation of fluid in the redundant chambers **124.**

Although it is believed that the operation of the device **20** will be largely self-evident to those skilled in the art from the preceding description of the construction and relationship of the parts, it may be briefly summarized that, in operating the device as a fluid motor, fluid under pressure is supplied to the inlet port **88** for flow through the passage **92** and the openings **93** and **94** in the valving block **24** into whichever of the relieved passages **100** in the member **30** are then in communication therewith, and thence through the corresponding neck passage **102** into the corresponding fluid displacement chamber **68,** the pressure within such chamber **68** exerting a force to move the member **30** radially outwardly from such chamber. Simultaneously fluid is being exhausted from the chambers **68** remote from those receiving a pressure input, with such fluid exhausting through the corresponding neck passages **102** and relieved passages **100** through corresponding

openings 98 and 97 in the valving block 24, thence into the passage 96 within the manifold 22 and to the external fluid return line coupled with exhaust port 90. As the chambers 68 are progressively filled and exhausted under the control of the valving communication alignment of the passages 100 with the openings 94 and 98 that occurs automatically upon orbital movement of the member 30, the latter is urged to orbit continually while being supported and confined to an orbital path by the eccentric assemblies 106. As the member 30 orbits, the teeth 64 upon the outer circumference of the member 30 walk around the teeth 62 on the inner circumferential surface of the hub 26 causing the latter to rotate with respect to the orbital member 30, the inner mem er 28 and the shaft 34. Rotational power is then derived from the device 20, operating as a motor, by suitable mechanical coupling with the rotating hub element 26. As previously noted, the device 20 lends itself well to applications requiring a reversible motor, in that, all that is required for reversing the direction of rotation of the hub 26 is to reverse the flow of fluid with respect to the fluid ports 88 and 90.

If it is desired to utilize the device 20 as a pump, the operation is essentially the same, except that mechanical rotative power is applied to the hub element 26 to turn the latter, which causes the member 30 to orbit under constraint of the eccentric assemblies 106, by virtue of the walking relationship between the epicyclic gear teeth 62 and 64. As the member 30 is thus moved in an orbital path, the individual chambers 68 are progressively placed in a fluid suction or fluid exhausting condition such that fluid may be pumped from an external line through the inlet port 88, thence through the fluid paths already traced but in the opposite direction, for delivery to an ouput line coupled with the port 90, the pumping action of the device 20 again being reversible, if desired, merely by reversing the direction of rotation in which the hub 26 is driven. Although the device 20 illustrated in FIGS. 1–8 and described in connection therewith is the currently preferred embodiment of the invention, it should be appreciated that the improvements incorporated by the invention into the illustrated device 20 would be equally applicable and effective with devices employing various modifications of construction or operation as, for example, utilization of the device 20 in a manner in which the hub element 26 is held stationary and motor power derived from or pumping power applied to the shaft 34 having parts 22, 24, 28 and 32 keyed thereto for rotation therewith, or a modified construction of the device 20 in which the chambers 68 are provided between the hub element 26 and the orbital member 30 with the epicyclic gear coupling being between the inner circumference of the member 30 and the outer circumference of element 28 and/or especially modifications of the device 20 employing differing numbers of chambers 68 and/or eccentric assemblies 106 than illustrated in the preferred embodiment, (it being noted also that the number of chambers 68 and the number of eccentric assemblies 106 need not be equal, although the illustrated construction is found to be convenient).

Turning attention now to the remaining embodiments illustrated in the drawings, it should first be observed that such additional embodiments are shown and described for two reasons. Firstly, such additional embodiments indicate the wide applicability of the improvements contemplated by the invention, and particularly the employment of eccentric crank or shaft mechanisms for mounting the orbiting member upon one of the other machine elements with respect to which it is to be supported and guided in an orbital path of travel, in connection with the great variety of basic constructions that are common to devices in this field. Actually, such additional embodiments are intended to illustrate the fact that the invention is applicable to device in which either of the inner and outer relatively rotatable machine elements may be the stator while the other serves as a rotor, to devices in which the intermediate orbiting member is mechanically coupled by epicyclic gearing to either the inner or outer machine elements and to either the stator or the rotor machine element, to devices in which the orbiting intermediate machine member is supported for orbital movement upon either the inner or outer machine elements and upon either the stator or the rotor machine elements, and to devices in which the intermediate orbiting member is coupled by fluid displacement means to either the inner or the outer machine elements or to both. Secondly, the remaining embodiments are intended to illustrate constructions in which the principles of the invention may be applied to present what essentially constitute new types of devices in the sense that combining the principles, structures and relationships of the invention into the overall combinations of elements produces devices of a new order or improved efficiency, economy and reliability. However, since the principles and constructions of the remaining embodiments are essentially similar to those of the preferred embodiment of FIGS. 1–8 with respect to the constructions involved in introducing the positive eccentric mounting means for confining the intermediate member to an orbital path and with respect to such features as the automatic control of valving, the provision of suitable fluid passages within the device structure, etc., and since the implementation of such principles and features should be now largely self evident to those skilled in the art from the preceding description of the preferred embodiment, the remaining embodiments have been shown and will be described only in such detail as would appear necessary to indicate to those skilled in the art the differences between such additional embodiments and the preferred embodiment already described in detail.

Thus, referring next to the embodiment of FIGS. 9–11, the device is generally designated 220 and will be recognized as involving the application of the invention to what is essentially a radial ball piston type energy translation device. The device 220 is also chosen, in contrast with the preferred embodiment of FIGS. 1–8, to illustrate employment of the invention in an energy translation machine in which the outer machine element comprises the stator, while the inner machine element serves as the rotor, and in which the intermediate orbiting member is supported and mounted upon the rotatable inner element.

In the device 220, an outer, stationary, cylindrical housing is presented by a pair of cylindrical frame members 222 and 224, spacer rings 226 and 228 and an outer ring gear element 230 all secured together as by bolt means 232. A rotatable shaft 234 is supported within the frame members 222 and 224 by roller bearings 236 and 238, along with a thrust washer 240 and a snap ring axial retainer 242. An inner machine element, rotatable with the shaft 234 is presented by and includes a pair of cylindrical side plates 244 and 246

respectively keyed to the shaft **234** as at **248** and **250**. The intermediate orbiting member **252** is generally annular and is disposed in the space between the shaft **234** and the outer, stationary gear element **230**. The intermediate orbiting member **252** is mounted upon the inner rotatable machine element and confined to an orbital path of travel with respect to the latter by a plurality of eccentric crank or shaft assemblies **254** each having a central portion **256** journaled in the member by roller bearings **258** and a pair of offset cylindrical end portions **260** and **262** of greater diameter and eccentricly journaled respectively in plates **244** and **246** by roller bearings **264** and **266**. Although, again, the employment of five eccentric assemblies **254** is shown for convenience of illustration, the number of eccentric assemblies **254** to be employed may be any number larger than two. Also, and as is equally applicable to the eccentric assembly **106** illustrated in connection with the embodiment of FIGS. **1–8**, the eccentric assemblies **254** may assume various configurations with respect to constructional detail as long as the necessary crank action and positive mounting relationship required to achieve the purposes of the invention are maintained; thus, the assembly **254** might employ separate eccentric crank shafts interfacing between the member **252** and the plates **244** and **246** respectively, or a set of single-ended crank shafts mounting the member **252** upon only one of the plates **244** and **246** could be used, etc.

The orbiting member **252** is provided with a plurality equal to three or more of radially extending cylinder bores **268**, each of which is open at its inner end and is closed at its outer end by a circumferential portion of the member **252** preferably constructed as an initial separate annular band **270** which may conveniently be fitted and secured upon the remainder of the member **252** after machining of the bores **268**. The outer band portion **270** of member **252** also carries thereon an inner set of outwardly facing gear teeth **272** adapted to mesh with an outer, interfacing set of gear teeth **274** on the inner surface of the outer element **230**, and which together present an epicyclic gear transmission coupling between the outer element **230** and the orbiting member **252**. Thus, the band **270** serves both as a cylinder head for the cylinder bores **268** and as the inner portion of the epicyclic gear transmission **272–274**.

A free floating ball piston **267** is provided within each of the cylinder bores **268** and adapted to roll axially of the latter as the member **252** orbits in a manner hereinafter described. A ball race **278** having an annular groove **280** therein is secured to the shaft **234** for rotation therewith, which provides a support for the balls **276**. A fluid displacement chamber **282** is thus presented within each cylinder bore **268** between the cylinder head band **270** and the ball piston **276**.

Fluid flow ports **284** and **286** are provided in the end plates **222** and **224** respectively. Port **284** is communicated with an annular ring passage **288** formed in the plate **222**, which in turn communicates with a set of slots **290** formed through the plate **226**. Similarly port **287** communicates with an annular passage **282**, in turn communicating with a plurality of slots **294** in the plate **228**, it being understood that there is a slot **290** and a slot **294** for each of the displacement chambers **282**, that the slots **290** may serve as fluid inlet apertures while the slots **294** serve as fluid exhaust apertures, or vice versa depending upon the external couplings that are made to the fluid ports **284** and **286**. Each chamber **282** is provided with a pair of opposed valving openings **296** and **298** extending from the cylinder bore **268** in opposite directions through the orbiting member **252** and disposed for valving communication with the fluid apertures **290** and **294** as the member **252** is orbited. The orientation of both the apertures **290** and **294** are indicated in dotted lines in FIG. **10**, merely to show positional relationships to the valving openings **296** or **298**, as the case may be, during orbiting of the member **252**, it being understood that the automatic valving action is substantially the same as described in detail in connection with the embodiment of FIGS. **1–8**. From this, it will be understood that the chambers **282** are progressively subjected to fluid pressure and exhaust cycling in successive progression, so that the forces in the various individual chambers **282** will cause the member **282** to orbit upon the eccentric assemblies **254** with respect to the inner machine element **244–246** and the axis of shaft **234** upon which the element **244–246** is mounted and keyed. As the member **252** thus orbits, the teeth **272** will "walk around" the teeth **274** of outer machine element **230**, which is stationary, so that the member **252** will rotate as well as orbit with respect to the outer machine element **230** and, in turn, will impart rotational movement and energy to the inner machine element **244–246** and the shaft **234**, when the device **220** is being employed as a motor, as is for the moment assumed. The direction of rotation of the orbiting member **252**, the inner machine element **244–246** and the shaft **234** may be reversed merely by reversing the pressure and exhaust couplings to ports **284** and **286**. Those skilled in the art will further appreciate that the device **220** may also be employed as a pump by applying rotative power to the shaft **234**, which will rotate the inner element **244–246** and the member **252**, whereupon the member **252** will be orbited as well as rotated by virtue of the eccentric assemblies **254** as the teeth **272** walk around the teeth **274**. Since the ball pistons **276** are effectively sealing the inner extremities of the bores **268**, and since the volumes of chambers **282** are progressively changing as the member **252** orbits, and since the apertures **290** and **294** are automatically being progressively and alternately aligned with the valving openings **296** and **298**, the device **220** will efficiently perform a fluid pumping operation drawing fluid into the port **284** and discharging the same from port **286**, or vice versa depending upon the direction in which the shaft **234** is driven.

The embodiment of FIG. **12** is similar in all essential respects to the embodiment of FIGS. **9–11**, and particularly so with respect to the eccentric mounting of the intermediate orbital member, the automatic valving arrangement, the provision of fluid passages and other miscellaneous details of construction, except that the embodiment of FIG. **12** will illustrate for those skilled in the art the application of the invention to a device **320** in which the radial ball pistons **276** of the embodiment of FIGS. **9–11** are replaced by hollow cylindrical virtual pistons **376**, and the inner ball race **278** is replaced by a polygonal support block **378**. Thus, it will be understood that in the device **320**, the rotatable shaft **334** carries thereon the polygonal block **378**, which is provided with a flat surface **302** for each of the hollow cylindrical pistons **376**. The pistons **376** are slidably mounted within cylindrical cylinder bores **368** formed in the orbiting member **352**. The orbiting mem-

ber 352 is again mounted for rotational movement with and orbital movement with respect to an inner machine element 344 by eccentric assembly 354 similar to those previously described. Each piston 376 is normally urged toward the corresponding surface 302 of the block 378 by a spring 304. It will be understood that an epicyclic gear coupling is provided in the manner previously described between the outer circumference of the orbiting member 352 and an outer machine element 330.

In operation, the device 320 functions in all respects similarly to the operation described for the embodiment of FIGS. 9–11, except that, as the member 352 orbits relative to the inner machine element 344 and the block 378, which are both secured to the shaft 334, the hollow pistons 376 merely provide a seal between the cylinder bores 368 and the surfaces 302 of block 378, so that the chambers 382 presented by the bores 368 and hollow pistons 376 progressively change in volume due to the virtual piston effect as the member 352 is orbited. Those skilled in the art will understand that various modifications could be made in the device 320, such as providing cylinder chambers 368 and pistons 376 of other than cylindrical cross section and that the device 320 may be operated in either direction or in either a motor or a pumping application, without departing from the principles of the invention, the vital improvement of the device 320 as compared with prior art concepts stemming from the provision of the eccentric assemblies 354 for positively mounting and confining the orbital member 352 to orbital motion with respect to the machine element 344, along with the precise valving thus permitted and the advantages thereby attained in accordance with the objects of the invention.

The embodiment of device 430 illustrated in FIGS. 13–15 is intended to illustrate the application of the invention to an energy transmission device of the type generally known to those skilled in the art as a "gerotor". The device 430 employes as its outer machine element, which for illustration may be assumed to be the stationary element thereof, a pair of side plates for 432 and 434 separated by an annular spacer 346, together with a manifold plate 438 facing the end plate 434, and all suitably secured together by bolts 440. A rotatable main shaft 442 is carried by bearings 444 and 446 in the end plates 432 and 434 respectively. The inner machine element, which is rotatable with the shaft 442 and keyed thereto as at 448 is provided with an inner gerotor gear element 450 having external teeth 453 thereon.

An orbiting stator member 452 is mounted upon and confined to orbital movement with respect to the end plates 432 and 434 by a plurality of eccentric crank or shaft assemblies 454, each of which includes a central cylindrical portion 456 journaled in the member 452 by bearings 458 and a pair of cylindrical end portions 460 and 462 respectively journaled in end plates 432 and 434 by bearings 464 and 466.

As best seen in FIG. 14, the orbital member 452 is provided with alternate teeth portions 468 and concavities 470 configured to slidingly mate with the teeth 453 of the inner gerotor element 450. As those skilled in the art will recognize there are one more outer teeth 468 and concavities 470 than there are inner teeth 453, presenting the conventional gerotor relationship in which the teeth 453 walk around the teeth 468 and concavities 470 to provide not only an epicyclic transmission arrangement but also a relationship presenting a successive series of fluid displacement chambers 472 between the element 450 and the member 452 at each successive stage of the walking movement between the teeth 453 and 468. It will also be understood that the relationship between the teeth 453 and the teeth 468 and concavities 470 also is capable of imparting orbital movement to the member 452 when the latter is freely floating, but only with considerable wear upon the teeth 453 and 468 and stringent constructional strength requirements when the member 452 is guided in its orbital movement only by the relationships mentioned.

In the device 430 contemplated by this invention however, the provision of the eccentric assemblies 454 positively and orbitally mounting the member 452 on the outer element 432–434 greatly relieves the forces and strains upon the teeth 453 and 468 and permits the latter to be constructed and employed with only those strengths and tolerances required for the epicyclic gear relationship and the progressive displacement chamber creating function characterizing the gerotor design.

The manifold plate 438 is provided with fluid pressure and exhaust ports 474 and 476 which communicate respectively with annular ring passages 478 and 480 formed in the end plate 434. The passage 480 communicates with a plurality of radial passages 482 in the end plate 434, each of which then communicates with an axial passage 484 through the plate 434 terminated in a fluid aperture 486 in the face of end plate 434 adjacent the member 452. The annular passage 478 is similarly communicated through the plate 484 with a plurality of fluid apertures 488 in the face of the plate 434 adjacent the member 452, there being a pair of fluid apertures 486 and 488 provided for each of the concavities 470 in the member 452.

A valving groove 400 is relieved or cut away in the member 472 for each of the concavities 470 to provide fluid communication with the displacement chambers 472 successively presented within the concavities 470 as the member 452 is orbited. As will be clear from FIG. 14, the valving grooves 490 automatically and progressively alternate being in communication with the fluid apertures 486 and 488 as the member 452 is orbited, thereby providing for sinusoidal variance between maximum pressure and maximum exhaust aperture phases of the valving cycle for each of the displacement chambers 472 successively and in synchronization with the orbiting of the member 452.

In the operation of the device 430 as a motor, the progressive, phased valving of fluid pressure and exhaust to the displacement chambers 472 causes the teeth 453 of the inner rotary element 450 to walk around the teeth and concavities 468 and 470 of the member 452, simultaneously imparting rotational movement to the inner element 450 and shaft 442 and orbital movement to the member 452. Since such orbital movement of member 432 is essential to the operation of a gerotor device, as well as to the precision control of valving, the eccentric assemblies 454 improve the efficiencies of the basic gerotor design by relieving a substantial amount of the stresses and friction that would otherwise exist between the element 450 and the member 452 in order for the former to guide the latter in an orbital path. It will be understood, of course, that the direction of rotation of the shaft 442 may be reversed by reversing the pressure and exhaust couplings

to the ports 474 and 476; that the device 430 may be employed as a pump by applying rotational power to the shaft 442 rather than fluid pressure differentials to the ports 474 and 476; and that various other constructional and operational modifications could be employed without sacrificing the advantages accruing from incorporation of the invention, including the eccentric assemblies 454, into a device of a gerotor type.

The illustrative embodiment shown as device 530 in FIGS. 16–18 is, in many respects, similar and even identical to gerotor device 430 shown and described in connectwion with FIGS. 13–15. Accordingly, portions of the device 530 essentially identical to similar portions of the device 430 will be similarly numbered and will not be again described in detail, except to note such material changes or variances as there may be. The device 530 illustrates the incorporation of the principles of the invention into an energy translation device embodying certain physical features of the gerotor design in combination with the provision of additional vane defined fluid displacement chambers between the outer machine element and the intermediate orbital member.

Parts of the device 530 similar in construction and function to parts described in connection with the device 430 include the end plates 432 and 434, the spacer 436 (with the exceptions hereinafter noted), the manifold plate 438, the bolt means 440, the shaft 442, the inner gerotor element 450, the intermediate orbiting member 452 (with the exceptions hereinafter noted), the eccentric mounting assemblies 454, the fluid ports 474 and 476, the passages 478, 480, 482 and 484, the grooves 490 and the valving apertures 486 and 488.

The orbiting member 452 of device 530 differs from that described in connection with device 430 in two material respects. First, the member 452 of the present embodiment additonally includes, in association with each groove 490, communicating with a concavity 470, a pair of further grooves 502 and 504 which are spaced on opposite sides of the groove 490 and communicate with the space 506 between the outer circumference of the member 452 and the inner circumference of the ring 436. The disposition of the grooves 502 and 504 associated with each of the grooves 490 is such that when the groove 490 is in valving communication with the fluid aperture 486, the groove 504 will be communicating with the fluid aperture 488, and when the groove 490 is communicating with the fluid aperture 488, the groove 502 will be communicating with the fluid aperture 486. Thus, it will be apparent that for each sector of the device 530 including a concavity 470, the space 506 will be coupled with the fluid exhaust while the concavity 470 is coupled with fluid pressure and vice versa.

The space 506 circumscribing the member 452 is divided into a plurality of fluid displacement chambers 508, their placement being one chamber 508 for each concavity 470 and radially aligned with the latter. The space 506 is thus divided by a plurality of shiftable vanes generally designated 510, which may be essentially similar in construction with the vanes 70 shown in FIG. 8. Each vane 510 has an inner cylindrical portion 512 pivotally received within a corresponding cylindrical slot 514 provided in the outer circumferential surface of member 452, which constitutes the second material difference between the member 452 in devices 530 and 430.

At the opposite and outer end of each vane 510 is a cylindrical end portion 516 which is pivotally and slidably received within a corresponding slot 518 provided in the inner circumferential surface of the ring 436 of device 530.

Thus, it will be understood that, in the device 530, the automatic valving provided by the grooves 490 and 502 and 504 in conjunction with the fluid apertures 486 and 488, and which is controlled by the orbiting of the member 452 in essentially the manner previously described, is effected to progressively subject not only the fluid displacement chambers 472 within the concavities 470, but also the outer fluid displacement chambers 508 to fluid conditions varying sinusoidally between maximum pressure and full exhaust, with each corresponding pair of chambers 472 and 508 being 180° out of phase with regard to such fluid cycling. It will be appreciated, therefore, that the simultaneous occurrence of a pressure phase within a given inner chamber 472 while its corresponding outer chamber 508 is in an exhaust phase produces an additive effect from the fluid energy available to even more positively move the member 452 into the orbital path in which it is guided and to which it is confined by the eccentric crank or shaft assemblies 454. Also, the employment of the outer chambers 508 to aid in imparting orbital movement to the member 452 still further relieves the stresses and friction between the teeth 453 and 468 and increases the efficiency of the chambers 472 for performing their gerotor fluid displacement function. As the member 452 is orbited by the fluid energy forces, in the application of the device 530 as a motor, the walking action between the teeth 453 and 468 provides an epicyclic gear coupling between the rotor element 450 and the orbiting member 452 and imparts rotational movement to the rotor element 450 and the shaft 442 as previously described in connection with the device 430. As with the device 430, the device 530 may operate in either direction upon a reversal in fluid connections and may alternately be used in a pumping application by applying, rather than deriving, rotative mechanical energy to the shaft 442.

From the illustrative embodiments of energy translation devices embodying the principles of the inventions that have been hereinbefore shown and described, it should be apparent, first, that the invention is well suited to accomplishing the objects and advantages mentioned above, secondly, that the invention is advantageously applicable in a wide variety of fluid motors, pumps, and the like, and, thirdly, that various minor modifications and changes could be made from the embodiments chosen for illustrative purposes without departing from the true spirit or substance of the invention. Accordingly, it should be understood that the invention is intended to be limited only by the fair scope of the claims that follow.

I claim:

1. In a device of the class including fluid motors, pumps and certain activators, meters, couplers and the like, in which energy is translated from fluid to mechanical or from mechanical to fluid manifestations thereof, the combination of:

a pair of elements,

said elements being relatively movable with respect to each other;

means for supporting said elements for relative rotational movement there between;

a member,
said member being relatively movable with respect to each of said elements respectively;
means for effecting both fluid and mechanical couplings between said member and one of said elements,
said coupling means including interengaging epicyclic gear means having cooperating tooth means on said member and said one element respectively, said tooth means on said member having a different number of teeth than said tooth means on said one element to provide a mechanical gear ratio different from unity between said member and said one element, said gear means presenting a plurality of fluid displacement chambers between said member and said one element, the effective volumes of said chambers being individually variable and at any given time dependent upon the relative positions of said member and said one element,
said coupling means additionally including means for selectively effecting fluid ingress and egress connections with said chambers in a predetermined order for the selective introduction or removal of fluid; and
further means, separate from and operably sufficient independently of said coupling means, for supporting said member for predetermined relative movements between said member and each of said elements respectively and for limiting said predetermined movements to relative orbital movement between said member and said other element and to relative orbital and rotational movements between said member and said one element,
said further means providing said support for the member and said limitation of relative movements between the member and the respective elements without reliance upon mechanical forces transmitted through said tooth means and comprising a plurality greater than two of spaced eccentric crank means intercoupling said member and said other element.

2. The invention of claim **1**, wherein the rotational axes of said crank means are parallel to and spaced away from the axis of relative rotation of said elements.

3. The invention of claim **1**, wherein said one element is a rotatable rotor, and said other element is a non-rotating stator.

4. The invention of claim **1**, wherein said elements are concentric about their axis of relative rotation, and said member is generally annular and disposed outwardly of said one element.

5. A gerotor type, low speed, high torque, internal transmission, fluid motor comprising:
an inner gerotor element having a central axis and a radially outwardly facing surface;
a second machine element;
means for supporting said elements for relative rotation about said axis;
a generally annular, outer gerotor member having a radially inwardly facing surface defining a central space within which said inner element is disposed;
means for effecting both fluid and mechanical couplings between said outer gerotor member and said inner gerotor element,
said coupling means including interengaging epicyclic gear means having cooperating tooth means on said inwardly facing surface of said outer gerotor member and said outwardly facing surface of said inner gerotor element respectively, said tooth means on said outer gerotor member having a greater number of teeth than said tooth means on said inner gerotor element to provide a transmission having a mechanical gear ratio different from unity between said outer gerotor member and said inner gerotor element, said gear means presenting a plurality of fluid displacement chambers between said outer gerotor member and said inner gerotor element, the effective volumes of said chambers being individually variable and at any given time dependent upon the relative positions of said outer gerotor member and said inner gerotor element,
said coupling means additionally including means for selectively effecting fluid ingress and egress connections with said chambers in a predetermined order for the selective introduction or removal of fluid; and
a plurality of eccentric crank means intercoupling said outer gerotor member with said second element to prevent relative rotation therebetween and to limit shifting movement of said outer gerotor member relative to said second element to orbital motion,
whereby introduction of fluid under pressure to said chambers selectively in said order causes driven relative rotation between said inner gerotor element and said outer gerotor member and between said inner gerotor element and said second element as said outer gerotor member is moved in said orbital motion thereof relative to said second element.

6. The invention of claim **5**, wherein said second element is part of an outer housing structure, and said inner gerotor element is mounted on a shaft rotatably journalled in said housing structure.

* * * * *